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ENERGY FLOWS IN NEW ENGLAND

HISTORICAL AND PROJECTED

ENERGY PROGRAM Technical Report

NEW ENGLAND REGIONAL COMMISSION

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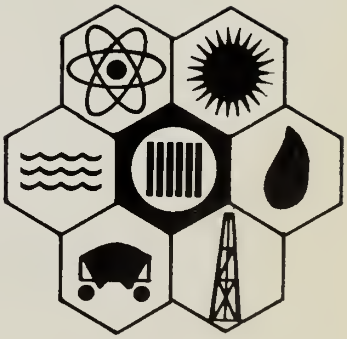

ENERGY PROGRAM Technical Report

NEW ENGLAND REGIONAL COMMISSION

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FOREWORD

This report is a product of the New England Regional Commission's Energy Research and Policy Formulation Program. The energy program will have several major outputs, including:

- A supply/demand balance for New England's energy requirements to 1990.
- Effects on New England from petroleum-related industrial development (including OCS development).
- New England gas industry development study.
- A review of electric power demand and supply trends and forecasts.
- Impacts of recent energy shortages and price increases on New England.
- Guidelines and a handbook for power plant siting.
- Legal and Institutional project, including a compendium and analysis of energy facility-related statutes, and an energy policy and decision-making study.
- The New England Fishing Industry and the projected impacts of Outer Continental Shelf development.

A complete list of Energy Program publications is available from the Commission's Energy Program Director.

The goal of the Energy Program is to supply the members of New England Regional Commission, which is comprised of the six New England Governors and a Federal Co-chairman appointed by the President, with reliable baseline information on New England's energy requirements and vulnerability, and to provide the Governors and the region with viable energy policy options and recommendations to guide New England's energy future. The Commission's Energy Program staff works closely with the Energy Advisors to the Governors and Energy Offices of the six New England states in formulating, analyzing and disseminating the output and results of the Energy Program, thereby achieving a measure of regional coordination in tackling the complex of energy problems facing the region.

The Energy Program is also involved in a broad range of projects including examination and response to national energy policy, Outer Continental Shelf policy formulation, regional petroleum and natural gas industry development programs, the New England Energy Management Information System, regional power management program, energy capability grants to assist state energy agencies, energy conservation plans, regional regulatory assistance program, demonstration projects program, U.S.—Canadian cooperation on energy matters, and technical policy assistance to the staffs of the New England Governors on other numerous matters of regional energy policy formulation and analysis.

We sincerely hope that this report will be of use and will provide some contribution to the management of New England's energy problems.

Russell F. Merriman
Federal Co-chairman

Thomas P. Salmon
Governor of Vermont
State Co-chairman

ACKNOWLEDGMENT

This report was prepared by Resource Planning Associates, Inc., under the supervision and direction of, and under contract with, the New England Regional Commission pursuant to the Commission's Energy Research and Policy Formulation Program. The statements, findings, and recommendations contained in the report are solely those of Resource Planning Associates, Inc., and do not necessarily reflect the views of the New England Regional Commission.

The New England Regional Commission was created under Title V of the Public Works and Economic Development Act of 1965, as amended. The Commission is a Federal/ State partnership whose membership is comprised of the Governors of the six New England states and a Federal Co-chairman appointed by the President.

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ENERGY FLOWS IN NEW ENGLAND

Historical and Projected

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INTRODUCTION

As the significance of the sharp changes in energy supply and price over the past three years became particularly apparent for the Northeast, the New England Regional Commission (NERCOM) launched a number of studies to document energy usage, estimate future trends in supply and demand, assess the effects of the 1973–1974 embargo, and evaluate the potential impacts of alternative energy developments in New England. As these studies have been completed, NERCOM has published and disseminated their results throughout the region in an effort to increase New England residents' understanding of basic energy needs, issues, and options.

This document is intended to be an education and communications vehicle for energy supply-demand forecasts. It presents the results of NERCOM's 1974 study of historical and projected energy supplies and demands—for New England overall and for each of the six states within the region—in a visual format of flow charts that enables the reader to comprehend quickly the overall energy supply-demand picture*. It is a useful reference† for both the energy policymaker and the layman because it:

- provides an immediate and complete overview of the types and amount of New England's energy usage in the perspective of relative fuel dependencies. For example, it clearly shows the region's heavy dependence on petroleum, and its relatively light dependence on natural gas.
- illustrates the efficiencies (i.e., useful versus lost energy) of fuel usage for each consuming sector, thereby highlighting the opportunities for waste heat utilization and technical improvements in equipment efficiencies.
- enables the reader to appreciate the historical changes and probable future trends in energy usage within the region.

Each energy flow chart follows a basic format which enables the reader to gain a clear picture of the complex patterns of energy usage by different consuming sectors in New England. A brief explanation of this format follows:

- The bar on the extreme left of each chart shows total New England energy usage broken down by state. The state or region being represented in the rest of the chart is shown in white within this bar.

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* The visual format used in this document was first developed and published in *Understanding the National Energy Dilemma,* a report by the Center for Strategic and International Studies, Georgetown University, for the Congressional Joint Committee on Atomic Energy, August 15, 1973.

† This document is bound in a looseleaf binder to provide for the easy replacement of existing charts with new ones as forecasts are updated.

- The data for the particular state or region are then enlarged in scale in the rest of the chart to provide a clear illustration of the energy flows. Fuels transported into the state or region are shown on the left. Depending on the state, these may include petroleum products, natural gas, coal, nuclear fuels, and hydroelectric power. Some portion of these fuels is used to generate electricity, which then is transmitted to the final consuming (end-use) sectors; i.e., residential, commercial, industrial, transportation, and miscellaneous. The remainder of the input fuels is consumed directly by the end-use sectors.

- On the right side of the chart the technical efficiencies of energy consumption within sectors are shown in terms of the useful work obtained (used energy) versus lost or unavailable energy. A substantial amount of the energy is lost in the generation of electricity.

- For each state and for the region as a whole, the increase in total energy consumption and change in the mix of fuels consumed over time can be seen by comparing the charts from 1966 through 1990. [The reader is cautioned not to compare different states' charts because their scales are not equal. For example, the 1966 energy flow charts for Massachusetts and Vermont (Figures 13 and 31, respectively) appear to be approximately the same size; however, in 1966 Massachusetts used 1.2 quadrillion Btu's and Vermont, only 70 trillion Btu's of energy.]

Energy consumption has been presented in Btu's on the flow charts. Should the reader wish to convert Btu's to physical units (e.g., barrels) for particular fuels, a conversion table has been provided below.

BTU CONVERSION TABLE

Fuel	Quantity	Btu Equivalent
Gasoline	Barrel (42 gal.)	5,248,000
Distillate fuel oils	Barrel	5,825,000
Residual fuel oil	Barrel	6,287,000
Liquefied petroleum gases	Gallon	95,500
Kerosine	Barrel	5,670,000
Natural gas	Cubic foot	1,031
Bituminous coal	Short ton	23,750,000
Electricity (output)	Kilowatt-hour	3,412
Hydropower (input)	Kilowatt-hour	10,379
Nuclear power (input)	Kilowatt-hour	9,000

Because large amounts of data were used to construct the complete energy supply-demand balance, and their underlying assumptions are important, definitions of the historical and projected data used are given in the two sections that follow. The first defines the data chosen and charted for the years 1966, 1974, 1980, 1990. The second documents the data sources.

DEFINITION OF CASES CHARTED

The basic references from which almost all the energy supply-demand data were obtained were three documents prepared for NERCOM by Arthur D. Little, Inc. (ADL):

> *Historical Data on New England's Energy Requirements,* September 1974.
> *Preliminary Projections of New England's Energy Requirements,* November 1974.
> Additional supply-demand scenario computer runs.

To obtain an historical picture of energy supply-demand, the year 1966 was chosen from the first document as the first year for which complete energy supply-demand information was available, yet long enough ago to show the marked changes in energy usage that occurred in the region from the mid-1960's to the mid-1970's—for example, the sharp decrease during that period in utility use of coal and the increase in nuclear fuel use.

Because the ADL studies were not completed until September of 1974, the energy supply-demand data for that year had to be estimated. Subsequently, however, ADL's Case III Medium Growth estimates have proved to be close enough to actual 1974 data to warrant charting only that case, drawn from the second document.

From the data in the second and third documents, two cases each for the years 1980 and 1990 were chosen and projected for each state and for the region as a whole. The two cases were chosen out of more than a dozen as being within the range of feasible alternatives, although the most likely alternative still remains to be determined by federal and state policies and outside events, such as fuel price changes. The two cases should provide the reader with some feeling for how energy flows could vary in New England, depending on such factors as future price levels and energy policies adopted; e.g., incentives for fuel substitution.

The energy projections for the two cases are described below. Both cases assume a continuation of the historical economic growth trends in the region, approximately a 2.3 percent annual growth in Gross Regional Product.

Case I:

ADL's Case III Medium Growth estimates for 1980 and 1990 were charted in this document as Case I. They extend the established (1966 and 1974) historical growth patterns in energy consumption modified to account for the likely shortage of natural gas and some voluntary energy conservation and fuel substitution, as well as a steady increase in the growth of nuclear-generated electric power.

Case II:

A second case was charted for the years 1980 and 1990 that reflects one of the additional scenarios projected by ADL: Conservation and Fuel Substitution. The scenario incorporates the likely shortage of natural gas and assumes the development of strong, planned energy conservation and fuel substitution programs—especially in the residential and commercial sectors—and a substantial growth in nuclear-generated electricity by 1990.

Thus, for each state and for the New England region as a whole, six energy flow charts have been constructed: 1966 Historical, 1974 Case I, 1980 Case I, 1980 Case II, 1990 Case I, and 1990 Case II.

DATA SOURCES

The approach and specific data used in constructing the energy flow charts were (refer to the sample chart and data references on pages 6 and 7):

1. **To document final energy-consuming sectors by type of fuel.** For 1966, data on fuel consumption by end-use sector were obtained from *Historical Data on New England's Energy Requirements**. End-use data for the years 1974, 1980, and 1990 were obtained from *Preliminary Projections of New England's Energy Requirements*. Data References 1—5 give the specific data sources used for this step.

2. **To document electrical generation and associated fuel inputs.** For 1966, both the generation of electricity (output) and electric plant fuel inputs were obtained directly from *Historical Data on New England's Energy Requirements.* Projected fossil fuel requirements for electrical generation for 1974, 1980, and 1990 were obtained directly from *Preliminary Projections of New England's Energy Requirements*, as was the assumption that hydroelectric power generation would remain constant at 1972 capacity. Nuclear fuel input requirements were not available by state for these three years, only for the region as a whole. Therefore, information on planned nuclear plant construction was used to obtain projections for 1980. The same information was used for 1990, together with the assumption that additional (currently unplanned) nuclear plants would be built in states that were projected to import electricity. Attachment A describes the development of the estimates for nuclear electric and total electric energy generation by state. Data references 6, 7, and 8 give the specific sources of data used.

3. **To determine total fossil fuel consumption requirements.** Total oil, gas, and coal requirements for each state were determined by aggregating the specific fuel requirements for each end-use sector and the electrical generation sector. Data references 9, 10, and 11 specify the aggregation procedure.

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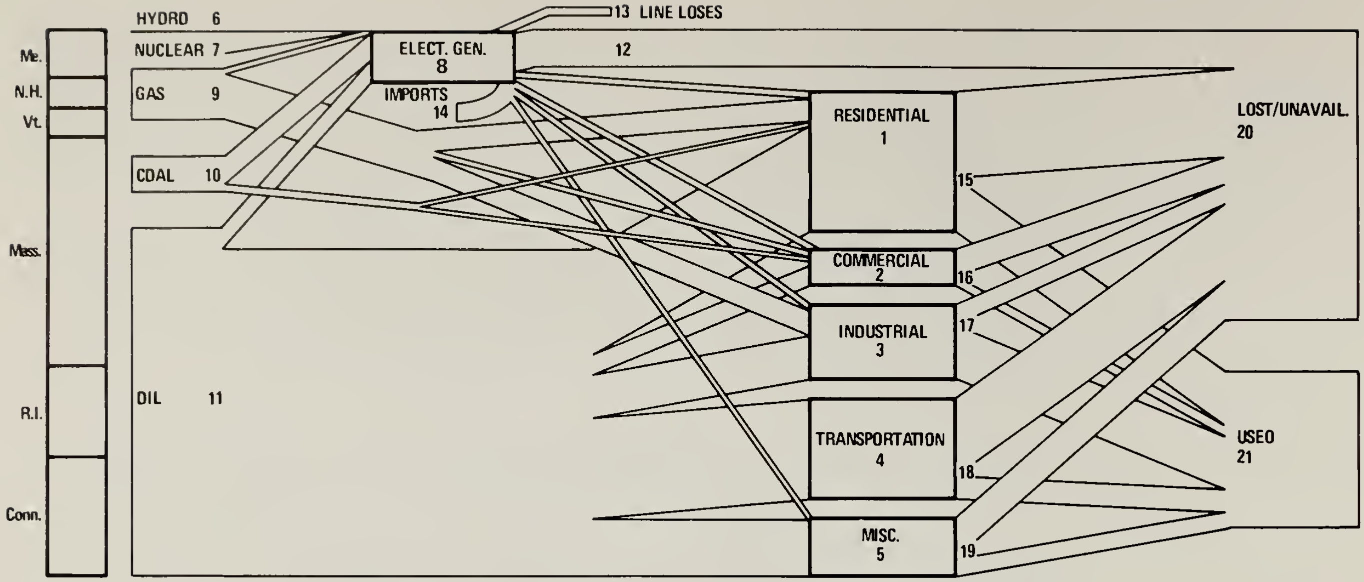
* A complete bibliography of data sources used can be found at the end of this document.

4. **To determine electrical generation efficiencies, line losses, and exports or imports.** For 1966, losses from converting fuels into electrical energy were taken directly from *Historical Data on New England's Energy Requirements.* For 1974, 1980, and 1990, electrical conversion losses were determined by applying assumed thermal efficiencies for hydro, nuclear, and fossil fuels to the electrical generation input fuel requirements for all years. Line losses then were calculated, and the remaining electricity available for consumption was compared with total electrical requirements of the end-use sectors to determine the imports or exports. Data references 12, 13, and 14 describe the sources used. Attachment A describes the data development in greater detail.

5. **To determine end-use sector efficiencies.** The efficiencies of residential, commercial, and industrial end-use sectors were derived primarily from the data contained in the 1972 Stanford Research Institute study, *Patterns of Energy Consumption in the United States.* Efficiencies for the transportation sector were obtained from *Understanding the National Energy Dilemma*, a report by the Center for Strategic and International Studies. Efficiencies for the miscellaneous sector were estimated by Resource Planning Associates. Data references 15—21 describe the sources used. Attachment B describes the development of used and lost energy estimates in greater detail.



SAMPLE CHART WITH DATA REFERENCE NUMBERS

DATA REFERENCES FOR ENERGY FLOW CHARTS

1. For 1966: Table C-1, *Historical Data on New England's Energy Requirements.*
   For 1974 and Case I projections: Table R-1, *Preliminary Projections of New England's Energy Requirements.*
   For Case II projections: Table R-1, Conservation and Fuel Substitution Scenario Runs.
2. For 1966: Table C-2, *Historical Data*
   For projected years: Table S-24, *Preliminary Projections*
3. For 1966: Table C-3, *Historical Data*
   For projected years: Table R-4, *Preliminary Projections*
4. For 1966: Table C-4, *Historical Data*
   For projected years: Table S-22, *Preliminary Projections*
5. For 1966: Table C-6, *Historical Data*
   For projected years: Table R-3, *Preliminary Projections*
6. For 1966: Table G-1, millions of kwh converted to trillion Btu's, *Historical Data*
   For projected years: Table G-1, 1972, millions of kwh converted to trillion Btu's. Assumed constant for all projected years.
7. For 1966: Table G-1, millions of kwh converted to trillion Btu's, *Historical Data*
   For projected years: *Atomic Industrial Forum, Inc.,* as adapted by RPA. (See Attachment A.)
8. For 1966: Fossil Fuel portion electric generation from Table C-5, *Historical Data*
   For projected years: Fossil Fuel portion of electric generation from Table R-2, *Preliminary Projections of New England's Energy Requirements* and the Conservation and Fuel Substitution scenario runs. Total electric generation is the sum of 6 (hydro), 7 (nuclear), and fossil fuel inputs.
9. Total amount of natural gas used in a state or region is the sum of the gas usage of all sectors identified previously.
10. Total amount of coal used in a state or region is the sum of the sectors' gas usage identified previously.
11. Total amount of oil used in a state or region is the sum of the sectors' oil usage identified previously.
12. For all years, conversion losses were determined by applying the thermal efficiencies of hydro, nuclear, and fossil electric generation to the amount of each of these fuels used. (See Attachment A.)
13. For all years, line losses are 8.8% of total electricity generated—drawn from *Energy and the Environment,* Council of Environmental Quality; pages 40, 46, 55, 57.
14. The amount of electricity imported or exported by a state in any particular year was determined by comparing total electricity generated (minus line losses) with total electricity consumed by the end-use sectors.
15. For all years charted, the used and lost energy for the residential sector was determined by applying technical efficiencies obtained from *Patterns of Energy Consumption in the United States* to total fuel consumed. (See Attachment B.)
16. For all years charted, used and lost commercial energy was determined by applying technical efficiencies obtained from *Patterns of Energy Consumption in the United States* to total fuel consumed. (See Attachment B.)
17. For all years charted, used and lost industrial energy was determined by applying technical efficiencies obtained from *Patterns of Energy Consumption in the United States* to total fuel consumed. (See Attachment B.)
18. For all years charted, used and lost transportation energy was determined by applying a 25 % technical efficiency from *Understanding the National Energy Dilemma* to total fuel consumed. (See Attachment B.)
19. For all years charted, miscellaneous used and lost energy was determined by applying a 30% technical efficiency to total fuel consumed. (See Attachment B.)
20. Total lost/unavailable energy is the sum of conversion losses (Ref. 12) and sectorial energy losses (Refs. 15-19).
21. Total used energy is the sum of the energy used by all sectors (Refs. 15-19).

Data on the nuclear generation of electricity by state and total electrical generation were developed from a set of assumptions applied to the ADL study data. These assumptions and associated calculations are described in this attachment.

NUCLEAR GENERATION OF ELECTRICITY BY STATE

For 1966, data on nuclear generation of electricity by state were available from *Historical Data on New England's Energy Requirements*. However, for 1974, 1980, and 1990, only data for total regional nuclear generation were available from the *Preliminary Projections of New England's Energy Requirements*. To develop data on nuclear generation by state for 1974 and 1980, the Atomic Industrial Forum's (AIF) list of existing and planned nuclear plants was used. (See Table A–1.) Data obtained from this source on the states' nuclear generation capacities in 1974 and 1980 equalled the capacities projected by NEPOOL (New England Power Pool) in *Preliminary Projections of New England's Energy Requirements*. However, not all potential nuclear plants for 1990 are on the AIF list because they have not yet been planned.

Therefore, in order to determine per-state figures for 1990, two assumptions were made:

> First, that New England as a whole would be self-sufficient in the generation of electricity; that is, the quantity of electricity demanded within New England would be generated within the region.
>
> Second, that the additional capacity from nuclear generation projected for the region as a whole would be filled by locating new plants in those states having projected deficiencies in electricity in 1990. Those states are Connecticut, Massachusetts, and Vermont. Each would be allotted additional nuclear-generated electrical facilities proportional to its total internal need for electricity until the deficiency was eliminated for the entire region. Table A–2 shows how these state-by-state nuclear plant estimates were developed for 1990.

Three steps were required to determine the total electrical generation data for each state: (1) thermal efficiencies were applied, (2) line losses were calculated, (3) and imports or exports were determined.

Assumptions about thermal efficiencies varied by type of electric power plant. The thermal efficiency of fossil fuel plants was assumed to be 31%, an assumption taken from *Preliminary Projections of New England's Energy Requirements*. The efficiency of hydroelectric plants was set at 32%, based on alternative electric plant fuel requirements. (A hydroelectric plant has no thermal combustion efficiency per se.) The source for this assumption was Fuels and Energy Data, Bureau of Mines, 1972. The thermal efficiency of nuclear power plants was assumed to be 38%, an assumption drawn from "Energy Technology to the Year 2000", *Technology Review*. These efficiencies applied to each of the fuel input requirements yielded the electrical generation and conversion loss data.

A certain portion of all electricity generated is lost in transmission. Transmission line losses were estimated at 8.8% of total generation, based on *Energy and the Environment: Electric Power*. Imports or exports for each state were calculated by comparing the electrical generation projections (minus line losses) with the electricity consumption projections of the end-use sectors.

Table A—1

Existing and Planned Nuclear Capacity by State

December 1, 1974
(MW)

State/Plant	1974	1980*	1990*
Connecticut			
Connecticut Yankee	575	575	575
Millstone 1	652	652	652
Millstone 2	—	830	830
Millstone 3	—	1,150	1,150
Total	1,227	3,207	3,207
Maine			
Maine Yankee	855	855	855
Seal Island 1	—	—	1,200
Total	855	855	2,055
Massachusetts			
Yankee	175	175	175
Pilgrim 1	655	655	655
Pilgrim 2	—	1,180	1,180
Pilgrim 3	—	—	1,150
Montague 1	—	—	1,150
Montague 2	—	—	1,150
Total	830	2,010	5,460
New Hampshire			
Seabrook 1	—	1,150	1,150
Seabrook 2	—	—	1,150
Total	—	1,150	2,300
Rhode Island			
Charlestown 1	—	—	1,200
Charlestown 2	—	—	1,200
Total	—	—	2,400
Vermont			
Vermont Yankee	540	540	540
Total	540	540	540
New England Total	3,452	7,762	15,962

SOURCE: Atomic Industrial Forum, Inc.

*Includes currently scheduled plants only.

Table A–2

Determination of Nuclear Electrical Generation by State

Case III Medium Growth–1990
(10^{12}Btu's)

Calculation Step [*]		New England	Connecticut	Maine	Massachusetts	New Hampshire	Rhode Island	Vermont
A.	Electricity consumed[†]	506.37	147.76	42.20	223.04	35.27	35.75	22.36
B.	Generation necessary to satisfy internal demand, assuming 8.8% line losses (A ÷ .912)	555.23	162.02	46.27	244.56	38.67	39.20	24.52
C.	Fossil fuel input[†]	443.16	131.05	23.23	190.80	79.76	10.45	7.90
D.	Generation by fossil fuel, assuming a 31% thermal efficiency (C x .31)	137.38	40.63	7.20	59.15	27.43	3.24	2.45
E.	Hydroelectric input[‡]	44.68	4.01	17.14	6.61	9.64	–	7.09
F.	Generation by hydroelectric, assuming 32% alternate fuel efficiency (E x .32)	14.62	1.32	5.63	2.17	3.15	–	2.33
G.	Total non-nuclear generation (D + F)	152.00	41.95	12.83	61.32	27.88	3.24	4.78
H.	Nuclear generation needed (B – G)	403.23	120.07	33.44	183.24	10.79	35.96	19.74
I.	Nuclear capacity required assuming 65% load factor (H ÷ .65)	620.35	184.7	51.45	281.9	16.6	55.3	30.4
J.	Projected nuclear generation based on utility plans (Atomic Industrial Forum, Inc.)	477.09	95.85	61.42	163.19	68.74	71.73	16.14
K.	Nuclear capacity excess (+) or shortfall (–) (J – I)	–143.26	–88.85	+9.97	–118.71	+52.14	+16.43	–14.26
L.	Allocation of 143.26 deficit to shortfall states to achieve an equal % of required capacity (M ÷ I)	+143.26	+59.6	0	+74.2	0	0	+9.5
M.	Total nuclear generation capacity (J + L)	620.35	155.45	61.42	237.39	68.74	71.73	25.64
N.	Actual nuclear generation, assuming 65% load factor (M x .65)	403.23	101.04	39.92	154.30	44.68	46.62	16.67
O.	Nuclear fuel input, assuming a 38% thermal efficiency (N ÷ .38)	1,061.13	265.89	105.05	406.05	117.58	122.68	43.87

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[*] Items in this column are lettered to allow for easy reference in subsequent items; e.g., A ÷ .912 refers to "energy consumed" in item A divided by .912.

[†] Fuel Consumption Data for 1990: *Preliminary Projections of New England's Energy Requirements*, prepared for the New England Regional Commission by Arthur D. Little, Inc., November 1974. Case III Tables R–1, R–5, S–22, S–24.

[‡] Assumed constant from 1972 consumption figures, according to: *Background for Projecting New England's Energy Requirements*, prepared for New England Regional Commission, by Arthur D. Little, Inc., December 1974, page 91.

ATTACHMENT B: Method of Calculating End-Use Sector Efficiencies

Virtually all fuels are subject to limits in thermodynamic or technical efficiency that dictate how much of the energy input is actually converted to usable energy, and how much is lost or unavailable. To determine these efficiencies and losses for each state for each of the years charted, the following methodology was used.

First, data on fuel used by end-use sectors (i.e., residential, commercial, industrial, transportation, and miscellaneous) were obtained from *Historical Data on New England's Energy Requirements* for 1966 and from *Preliminary Projections of New England's Energy Requirements* for 1974, 1980, and 1990. Table B—1 breaks out these data for New England in total for 1990.

Second, figures on the distribution of each fuel within the residential and commercial sectors obtained from *Residential and Commercial Energy Use Patterns, 1970—1990*, were applied. For example, looking at Table B—1, in the year 1990 natural gas consumption in the residential sector would be 114.27 trillion Btu's. Of that amount, 78% would be allocated to space heating, 16% to water heating, 4% to cooking, and 2% to appliance/lighting/other uses. (See Table B—2.) Then, the used versus lost or unavailable energy was calculated for each component use by applying the technical efficiencies shown in Table B—3 and aggregating them to obtain totals for the sectors overall.

In the industrial sector, the technical efficiency of energy end-use was based primarily on the efficiency of each fuel in producing steam. The exception was electrical energy; its end-use efficiency was based on electric drive applications. These efficiencies were applied to the fuel usage breakdown shown in Table B—1, and then aggregated to obtain used versus lost or unavailable energy for the sector overall.

In the transportation sector, the technical efficiency of all fuels (primarily motor gasoline and aviation fuels) was assumed to be 25%. The technical efficiency of fuels in the miscellaneous sector was estimated to be 30%, an average of fuel efficiencies of motor vehicles and military uses (mainly transport uses). Both the transportation and miscellaneous sector efficiencies were then applied to those sectors' fuel usage to determine used versus lost or unavailable energy.

Table B—4 shows the results of the calculations of used versus lost energy by type of fuel, aggregated to sector totals.

Table B—1

Fuels Consumed by Sector—New England 1990

(Trillion Btu's)

Fuel	Residential	Commercial	Industrial	Transportation	Miscellaneous
Coal	.01	—	.01	—	—
Natural gas	114.27	45.51	54.69	—	—
Petroleum products total	570.45	943.09	299.37	1117.10	95.29
Liquified petroleum gases	7.52	3.9	—	—	.73
Gasoline	—	—	—	972.07	5.14
Kerosine	43.37	—	—	51.58	9.05
Distillate fuel oils	519.56	368.74	85.54	78.13	27.88
Residual fuel oil	—	570.45	213.83	15.32	52.49
Electricity	226.15	171.52	103.64	—	5.06
Total Fuel Consumption	910.88	1160.12	457.71	1117.10	100.35

SOURCE: *Preliminary Projections of New England Energy Requirements—Case III,* prepared for NERCOM by Arthur D. Little, Inc. Tables R—1, S—24, R—4, S—22, and R—3,respectively.

Table B–2

Percentage Consumption of Fuels by End-Use Within Sectors—Northeast U.S.

	Coal		Natural Gas		Petroleum Products		Electricity	
Sector/ End Use	1970	1990	1970	1990	1970	1990	1970	1990
Residential								
Space Heating	93%	—	71%	78%	89%	93%	7%	11%
Water Heating	7	—	19	16	11	7	16	22
Air Conditioning	—	—	—	—	—	—	2	4
Cooking	—	—	8	4	—	—	7	9
Appliance, Lighting, Other	—	—	2	2	—	—	68	54
Total	100%	—	100%	100%	100%	100%	100%	100%
Commercial								
Space Heating	93%	—	73%	80%	91%	93%	4%	5%
Water Heating	7	—	18	15	9	7	25	31
Air Conditioning	—	—	—	—	—	—	5	8
Refrigeration	—	—	7	3	—	—	10	13
Appliance, Lighting, Other	—	—	2	2	—	—	56	43
Total	100%	—	100%	100%	100%	100%	100%	100%

SOURCE: *Residential and Commercial Energy Use Patterns, 1970–1990,* Federal Energy Administration, Project Independence Report, November 1974, Tables A.b and A.d for Northeast U.S.

Table B—3

Technical Efficiency of Energy End-Use
(Percent)

Sector/ End Use	Coal	Natural Gas	Petroleum Products	Electricity
Residential*				
Space Heating	55%	75%	63%	95%
Water Heating	15	64	50	92
Air Conditioning	–	30	–	50
Cooking	–	37	37	75
Other	–	47	47	57
Commercial*				
Space Heating	70	77	76	95
Water Heating	70	64	50	92
Air Conditioning	–	30	–	50
Refrigeration	–	–	–	50
Lighting	–	37	37	75
Industrial*	70	64	68	90
Transportation†	–	–	25	–
Miscellaneous‡	–	–	30	30

SOURCES: **Patterns of Energy Consumption in the U.S.*, Table 5, Stanford Research Institute. As adapted by RPA estimates.

†*Understanding the National Energy Dilemma*, p. 5.

‡RPA estimates.

Table B–4

Calculation Worksheet for Determining Used and Lost Energy by Sector
New England—1990

Sector/ End Use	Coal			Natural Gas			Petroleum Products			Electricity			Total Sector Energy		
	Total	Used	Lost	Total	Used	Lost	Total	Used	Lost	Total	Used	Lost	Total	Used	Lost
Residential															
Space Heating	.01	.01	—	89.13	66.85	22.28	530.52	334.23	196.29	24.88	23.63	1.25			
Water Heating	—	—	—	18.28	11.70	6.58	39.93	19.97	19.96	49.75	45.77	3.98			
Air Conditioning	—	—	—	—	—	—	—	—	—	9.05	4.52	4.53			
Cooking	—	—	—	4.57	1.69	2.88	—	—	—	20.35	15.27	5.08			
Other	—	—	—	2.29	1.07	1.22	—	—	—	122.12	69.61	52.51			
Total Residential	.01	.01	—	114.27	81.31	32.96	570.45	354.20	216.25	226.15	158.80	67.35	910.88	594.32	316.32
Commercial															
Space Heating	—	—	—	36.40	28.03	8.37	877.07	665.58	211.49	8.58	8.15	.43			
Water Heating	—	—	—	6.83	4.37	2.46	66.02	33.01	33.01	53.17	48.92	4.25			
Air Conditioning	—	—	—	—	—	—	—	—	—	13.72	6.86	6.86			
Refrigeration	—	—	—	1.37	.51	.86	—	—	—	22.30	11.15	11.15			
Lighting	—	—	—	.91	.34	.57	—	—	—	73.75	55.32	18.43			
Total Commercial	—	—	—	45.51	33.25	12.26	943.09	698.59	244.50	171.52	130.4	41.12	1160.12	862.24	297.88
Industrial	.01	.01	—	54.69	35.0	19.69	299.37	203.57	95.80	103.64	93.28	10.36	457.71	331.86	125.58
Transportation	—	—	—	—	—	—	1117.10	279.28	837.82	—	—	—	1117.10	279.28	837.82
Miscellaneous	—	—	—	—	—	—	100.35	30.11	70.24	—	—	—	100.35	30.11	70.24

BIBLIOGRAPHY

Arthur D. Little, Inc., *Background for Projecting New England's Energy Requirements,* prepared for the New England Regional Commission, C—77271, December 1974.

Historical Data on New England's Energy Requirements, prepared for the New England Regional Commission, C—77271, September 1974.

Preliminary Projections of New England's Energy Requirements, prepared for the New England Regional Commission, C—77271—01, November 1974.

Atomic Industrial Forum, Inc., *Nuclear Power Plants in the U.S.,* prepared for Public Affairs and Information Program, December 31, 1974.

Bureau of Mines, *Fuel and Energy Data,* Department of Interior, 1972.

Council on Environmental Quality, *Energy and the Environment: Electric Power,* August 1973.

Residential and Commercial Energy Use Patterns, 1970—1990, Project Independence Task Force Report, November 1974.

"Energy Technology to the Year 2000," *Technology Review.* Cambridge: MIT, 1972.

Federal Energy Administration, *Project Independence Report,* November 1974.

Joint Committee on Atomic Energy, *Understanding the National Energy Dilemma,* published by the Center for Strategic and International Studies, August 15, 1973.

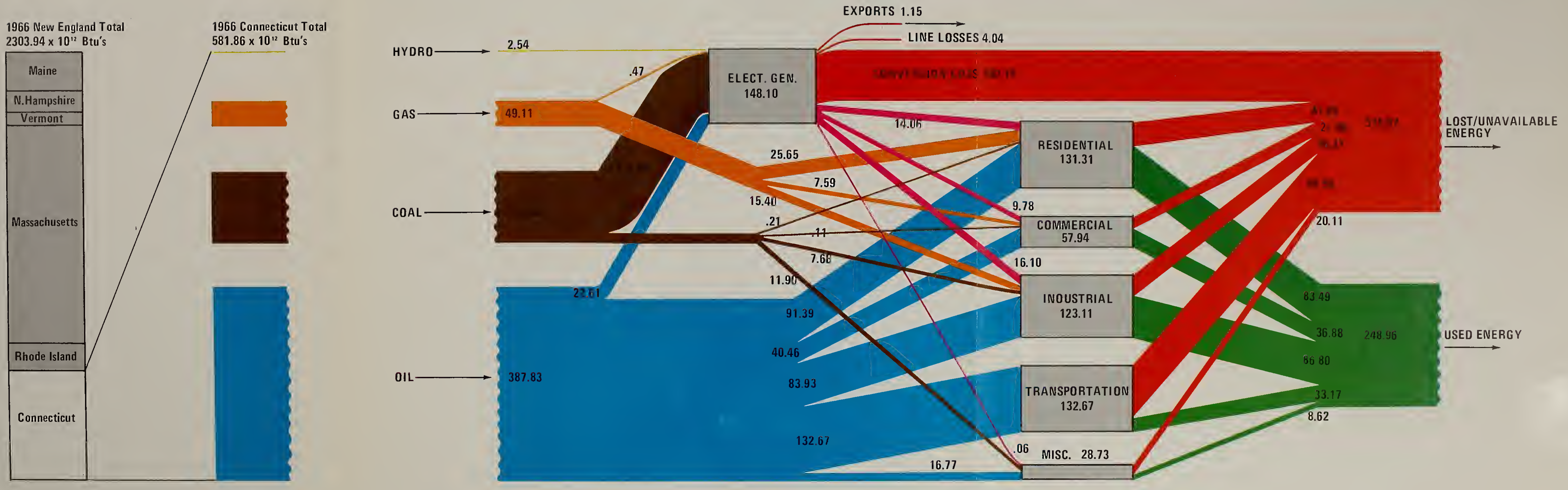
Stanford Research Institute, *Patterns of Energy Consumption in the United States,* prepared for Office of Science and Technology, Executive Office of the President, January 1972.

ENERGY
FLOW
CHARTS

EXHIBIT

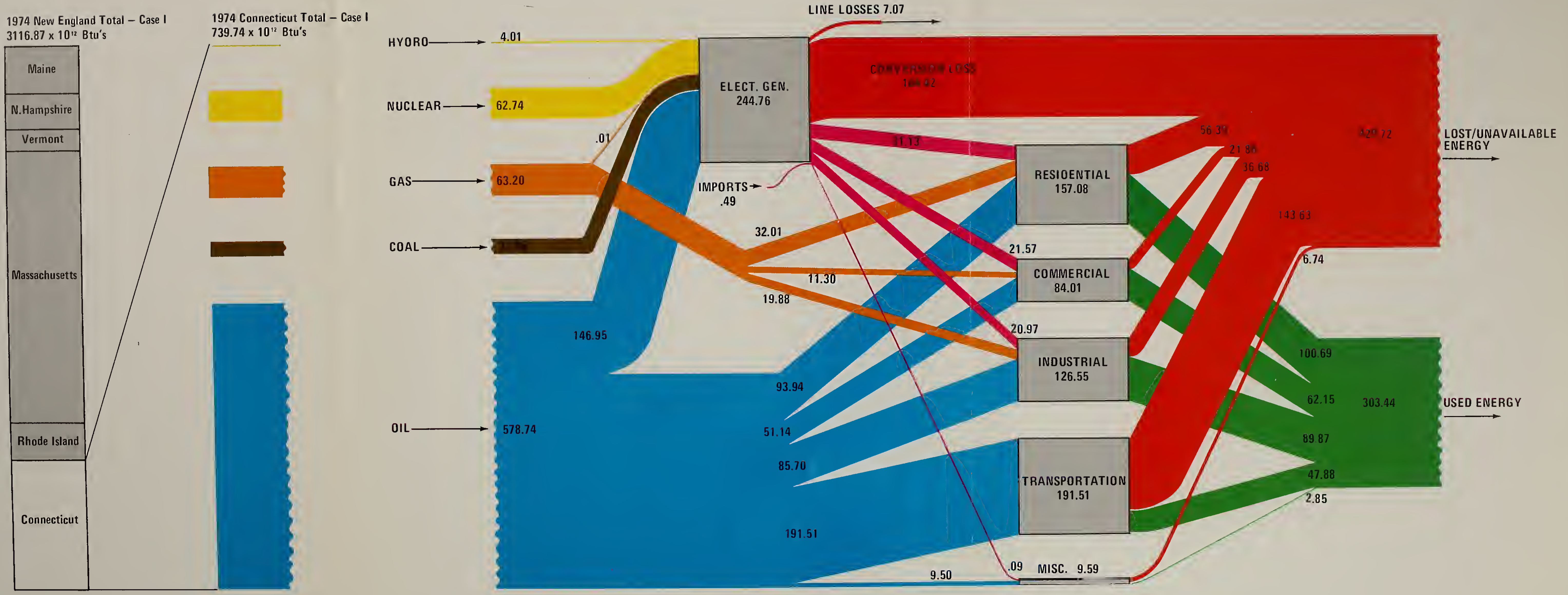
1

1966 CONNECTICUT ENERGY FLOWS
(x 10^{12} Btu's)



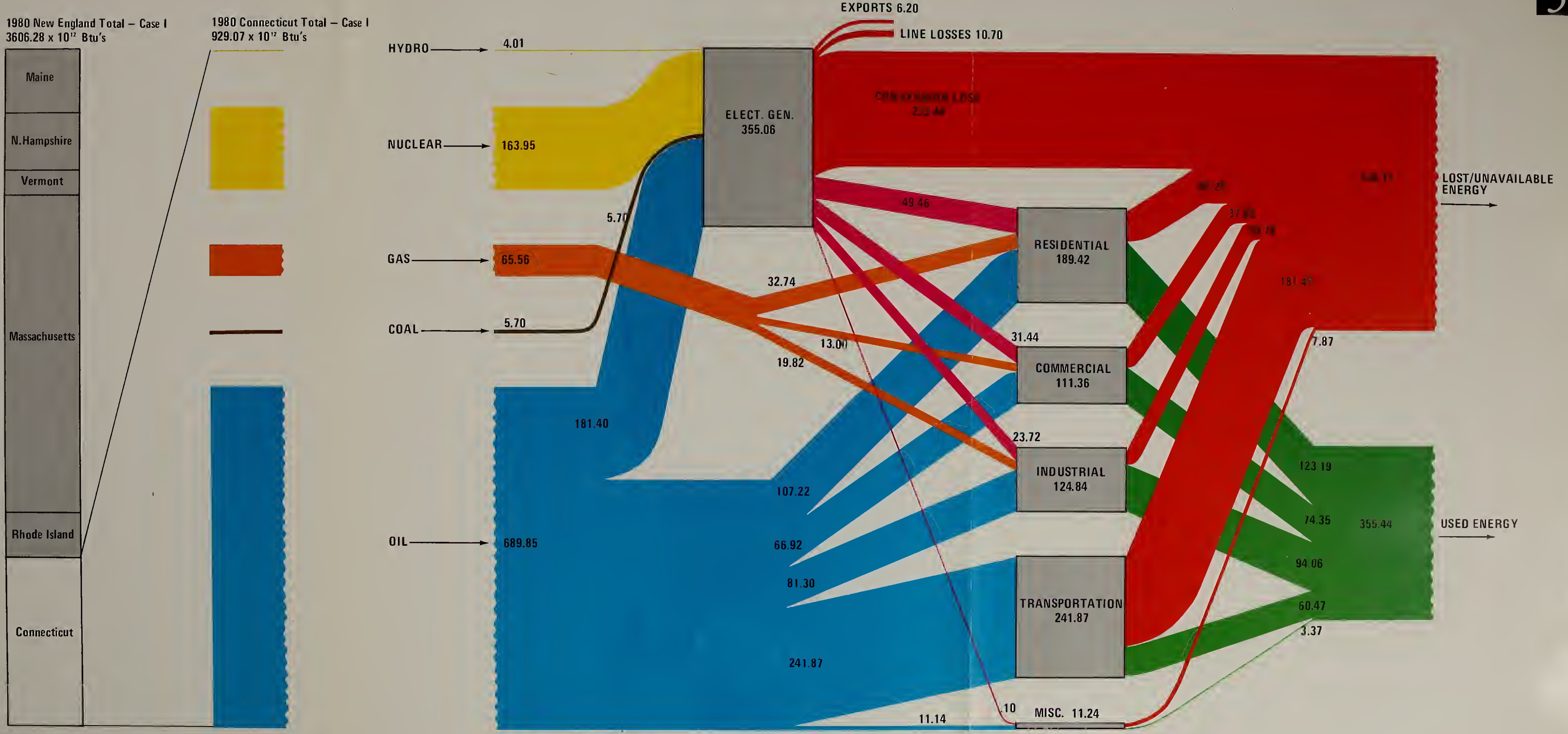
1974 CONNECTICUT ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
2



1980 CONNECTICUT ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT 3



1980 CONNECTICUT ENERGY FLOWS — CASE II
(x 10^{12} Btu's)

EXHIBIT 4

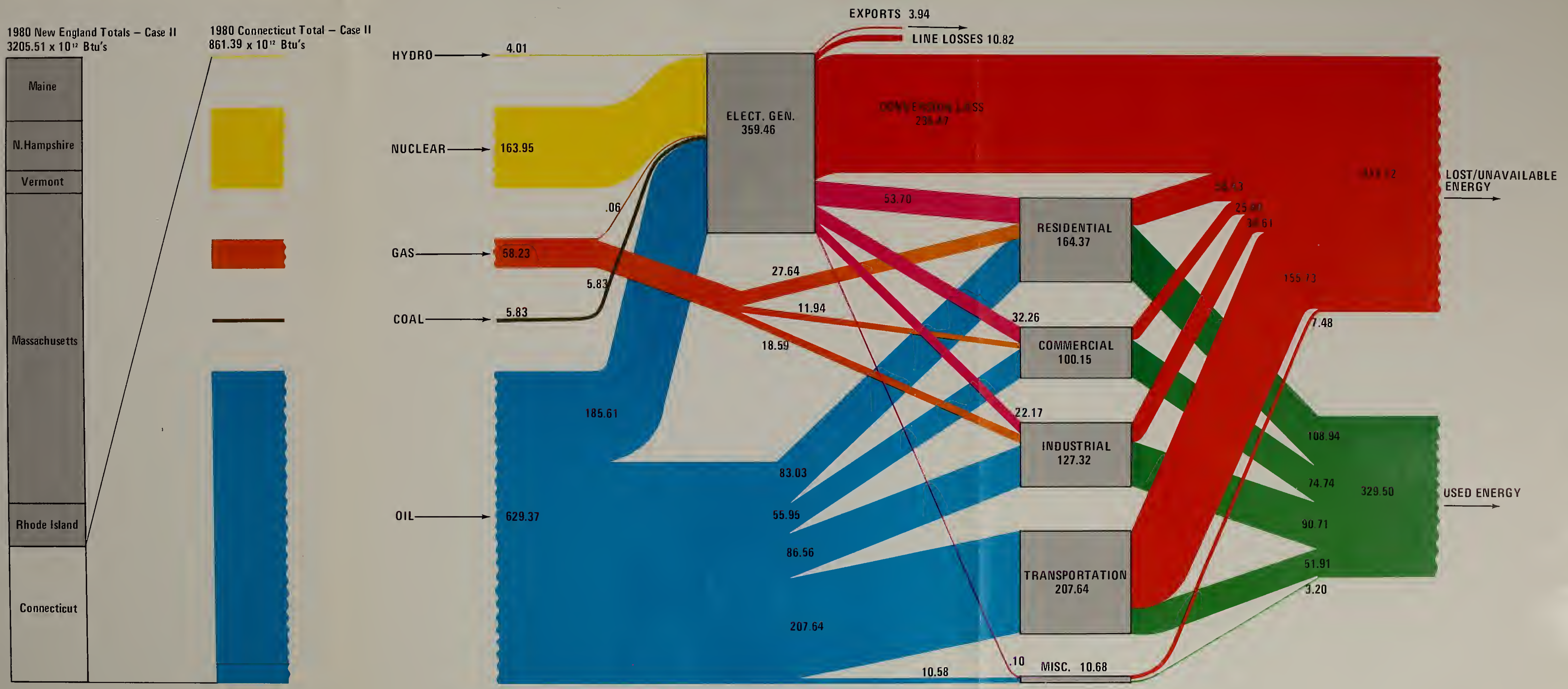
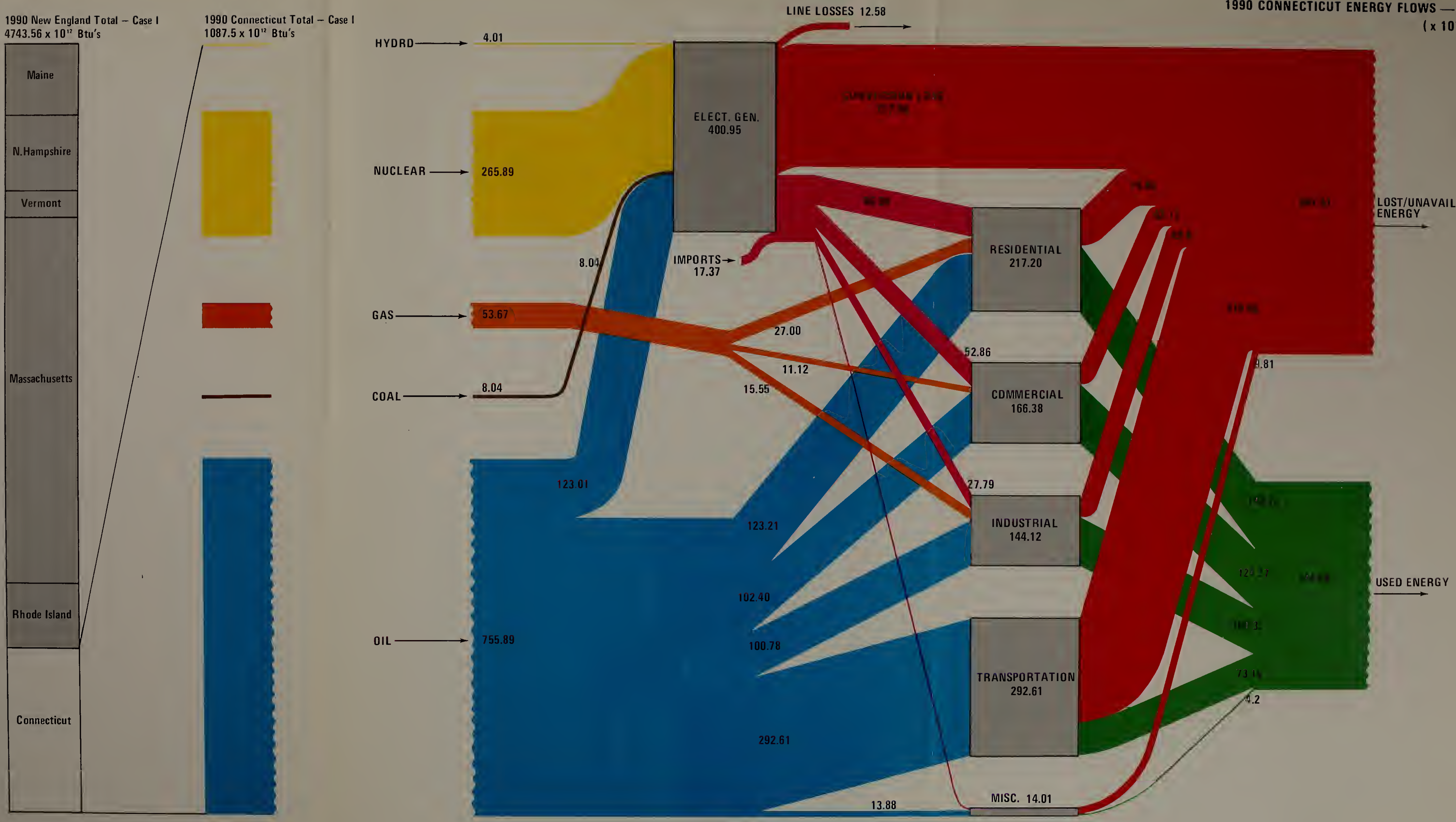


EXHIBIT 5

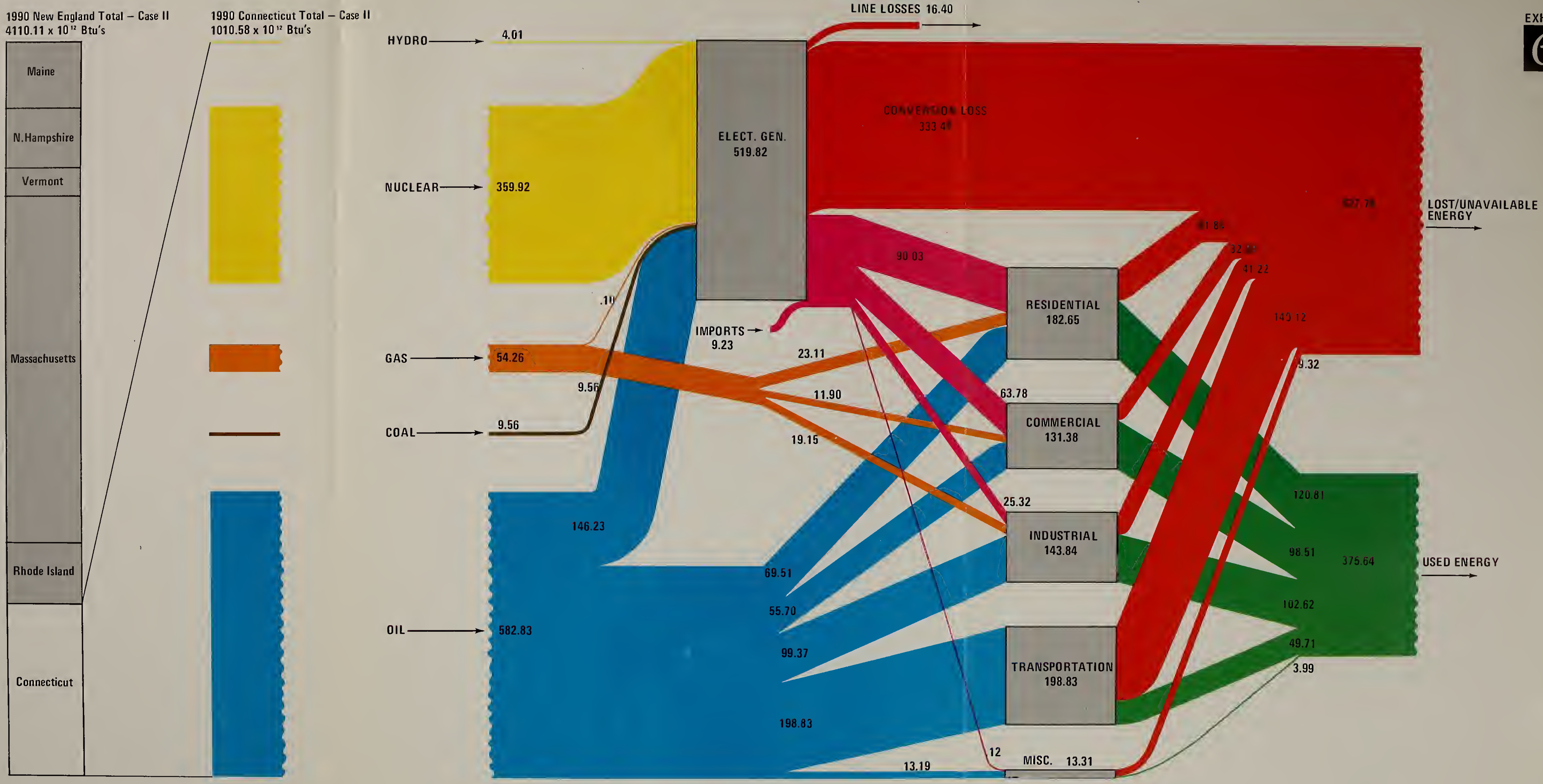
1990 CONNECTICUT ENERGY FLOWS — CASE I
(x 10^{12} Btu's)



EXHIBIT

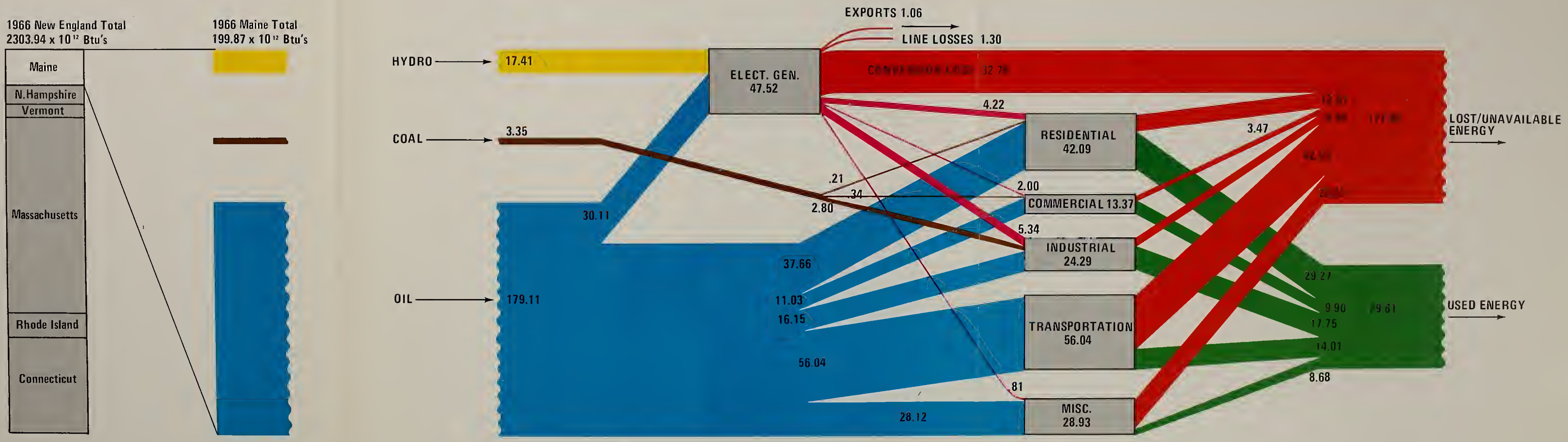
6

1990 CONNECTICUT ENERGY FLOWS — CASE II
(x 10^{12} Btu's)



1966 MAINE ENERGY FLOWS
(x 10^{12} Btu's)

EXHIBIT
7



1974 MAINE ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
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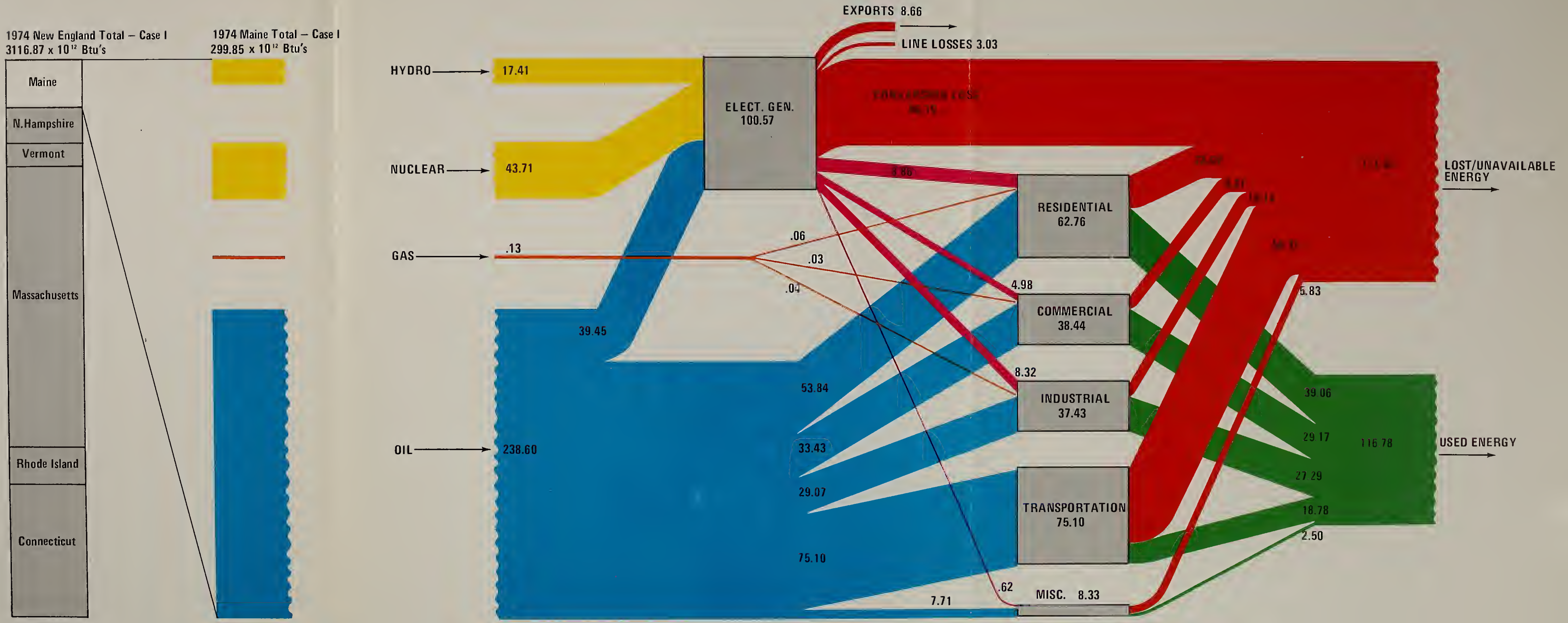

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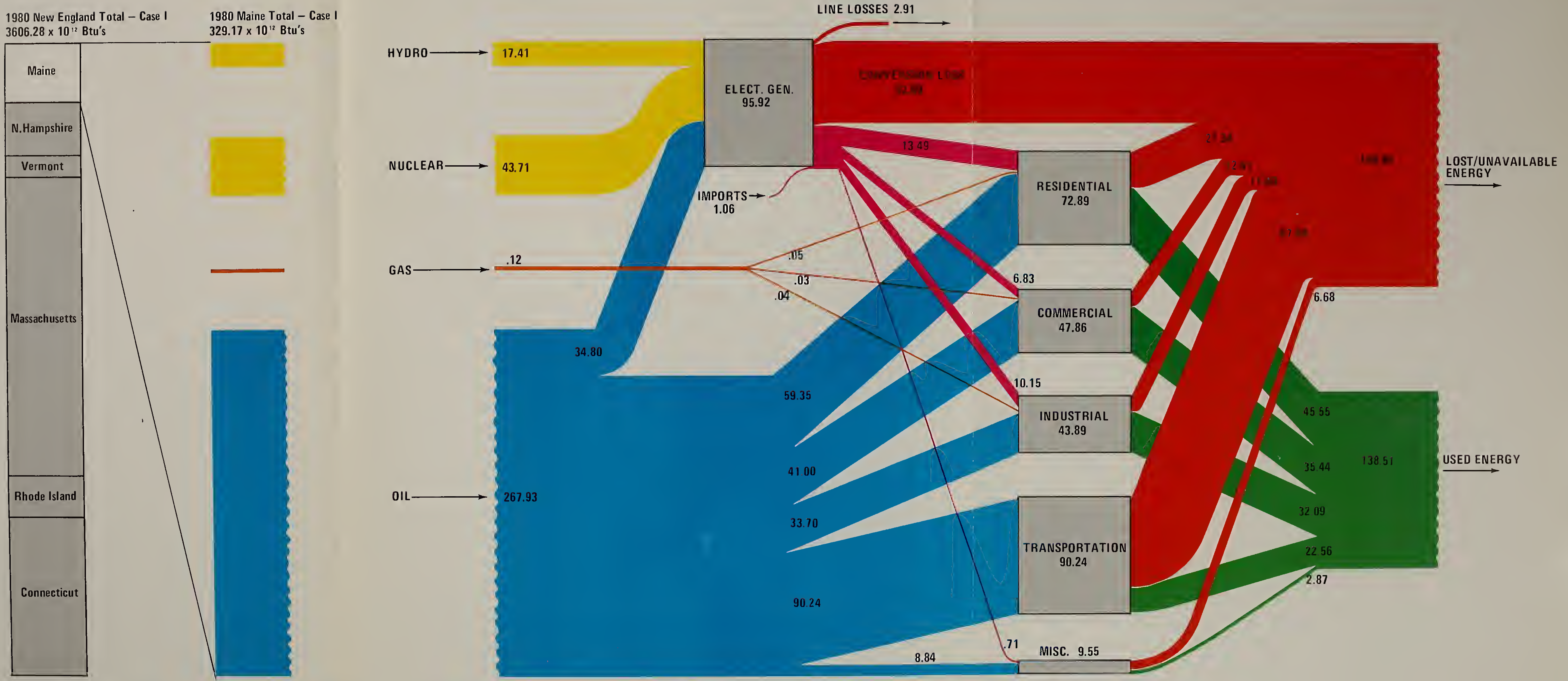
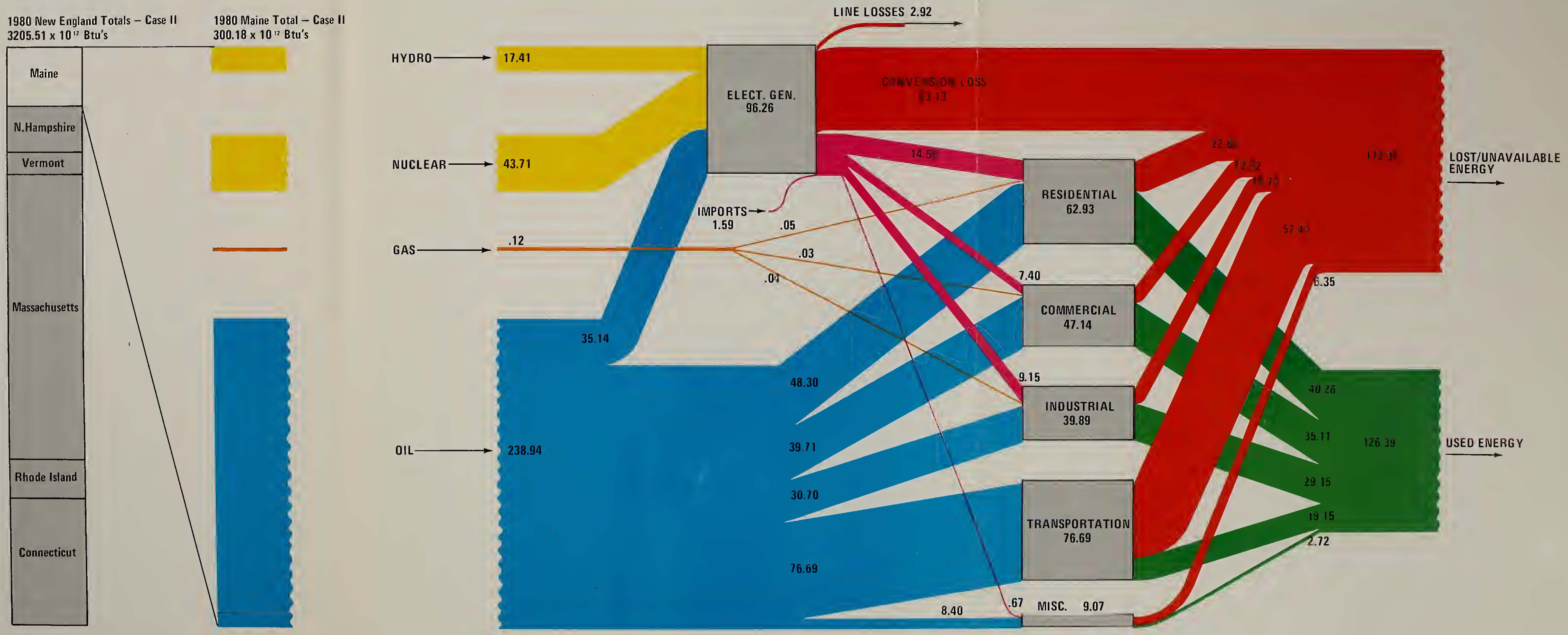
1980 MAINE ENERGY FLOWS — CASE I
(x 10^{12} Btu's)



1980 MAINE ENERGY FLOWS — CASE II
($\times 10^{12}$ Btu's)

EXHIBIT 10



1990 MAINE ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

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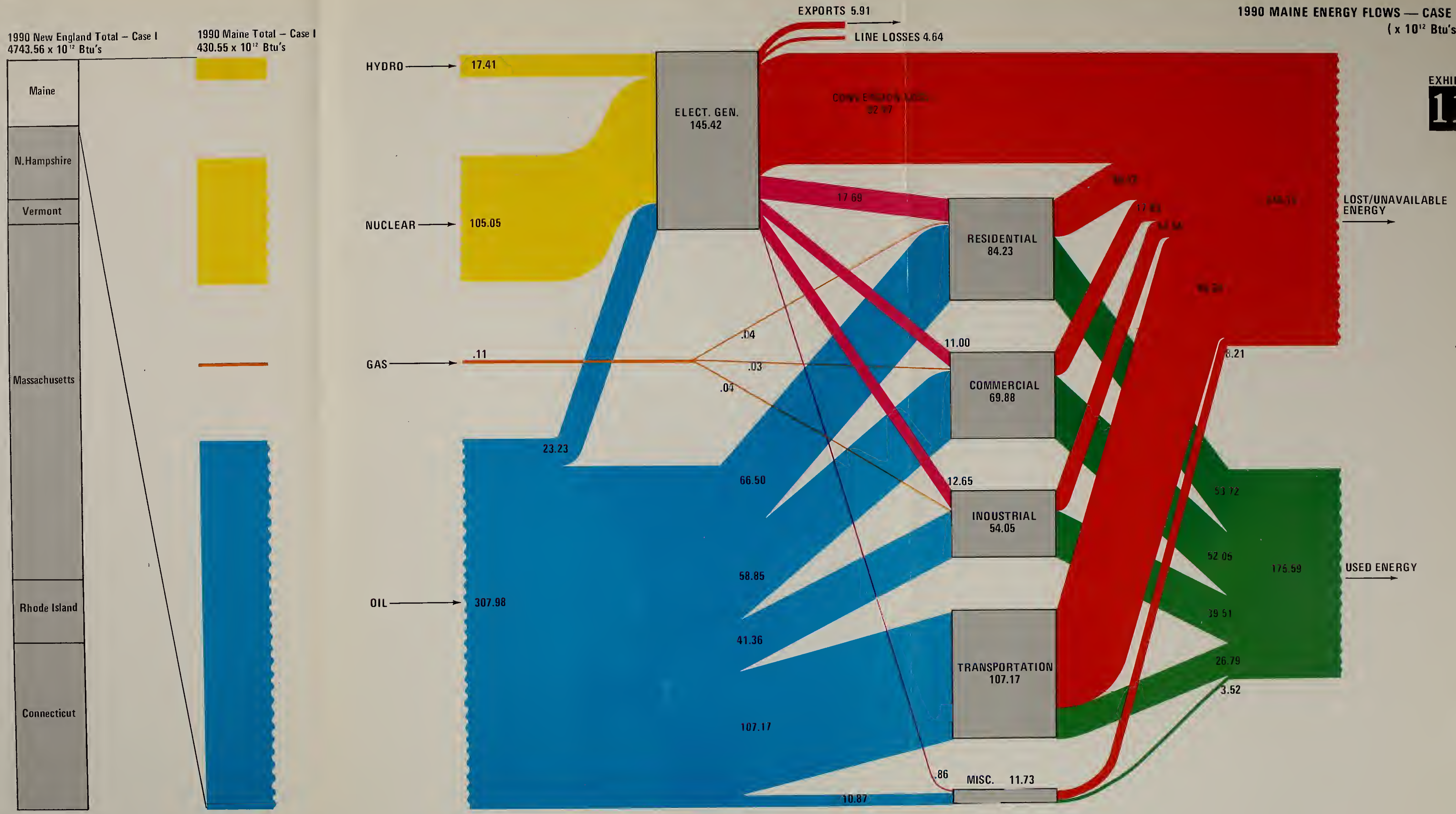

1990 MAINE ENERGY FLOWS — CASE II
(x 10^{12} Btu's)

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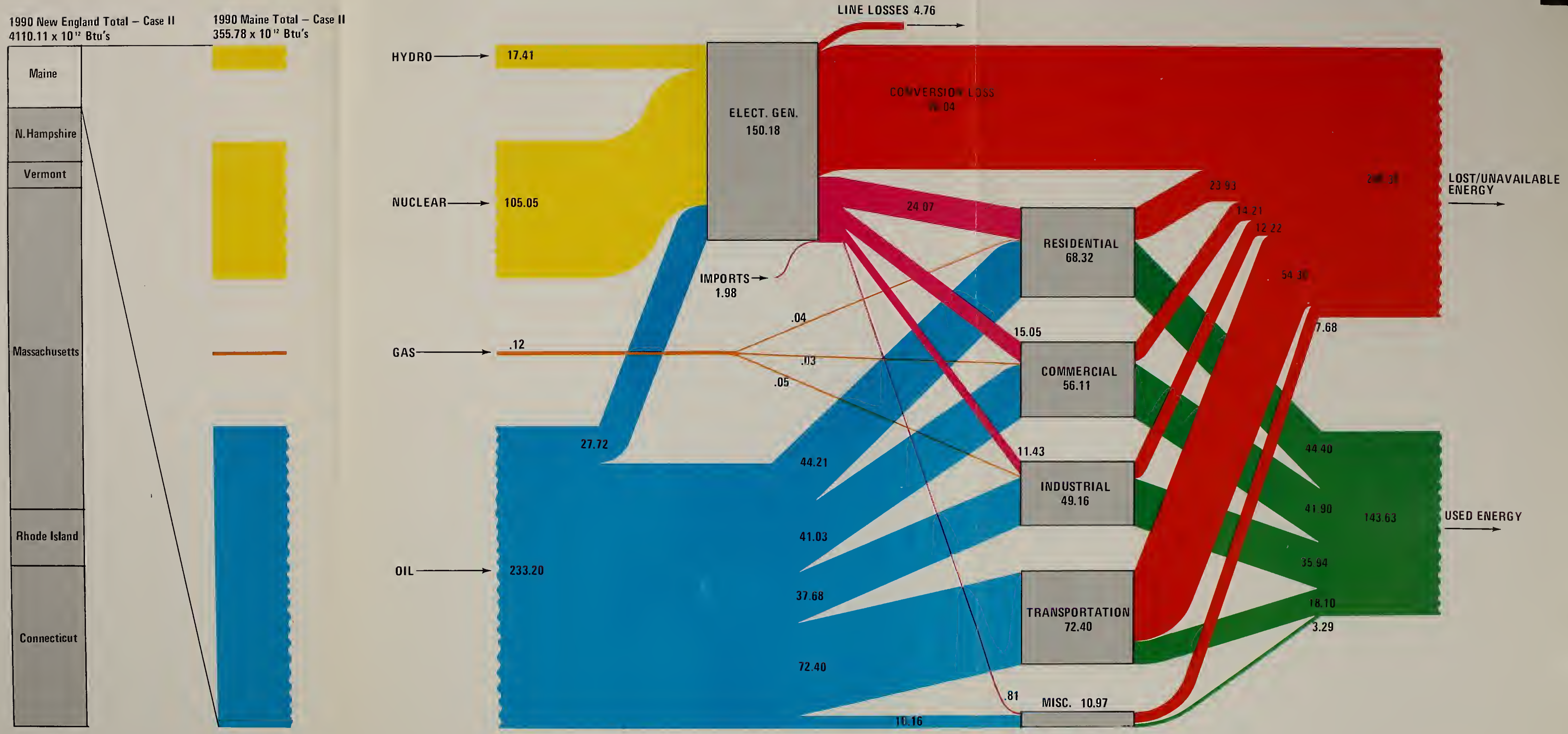

1966 MASSACHUSETTS ENERGY FLOWS
(x 10^{12} Btu's)

EXHIBIT
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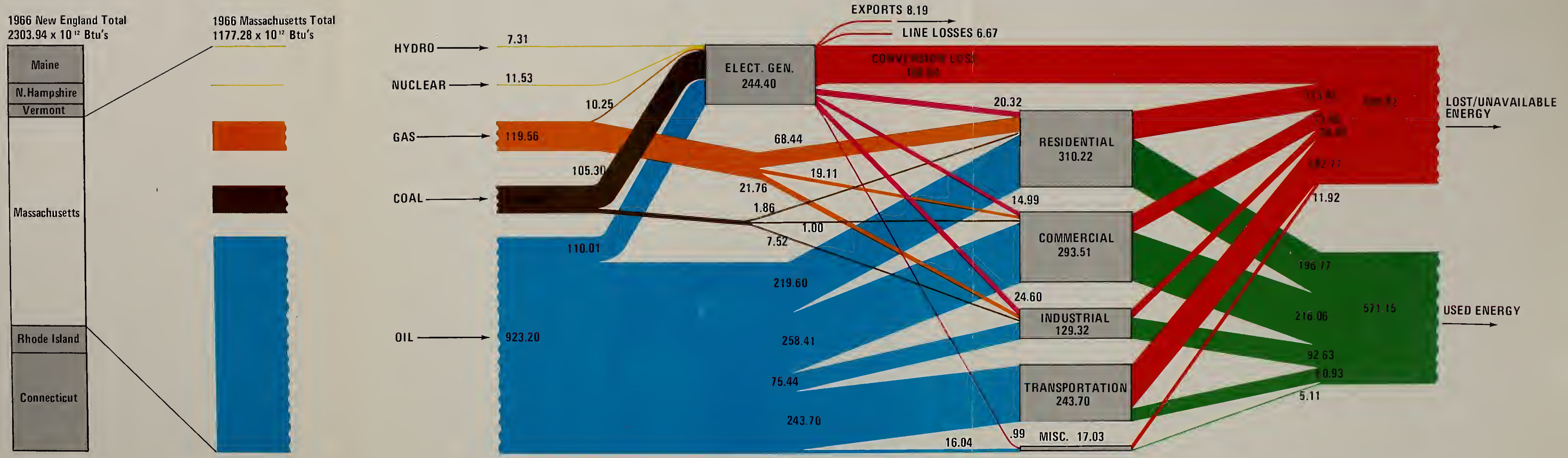
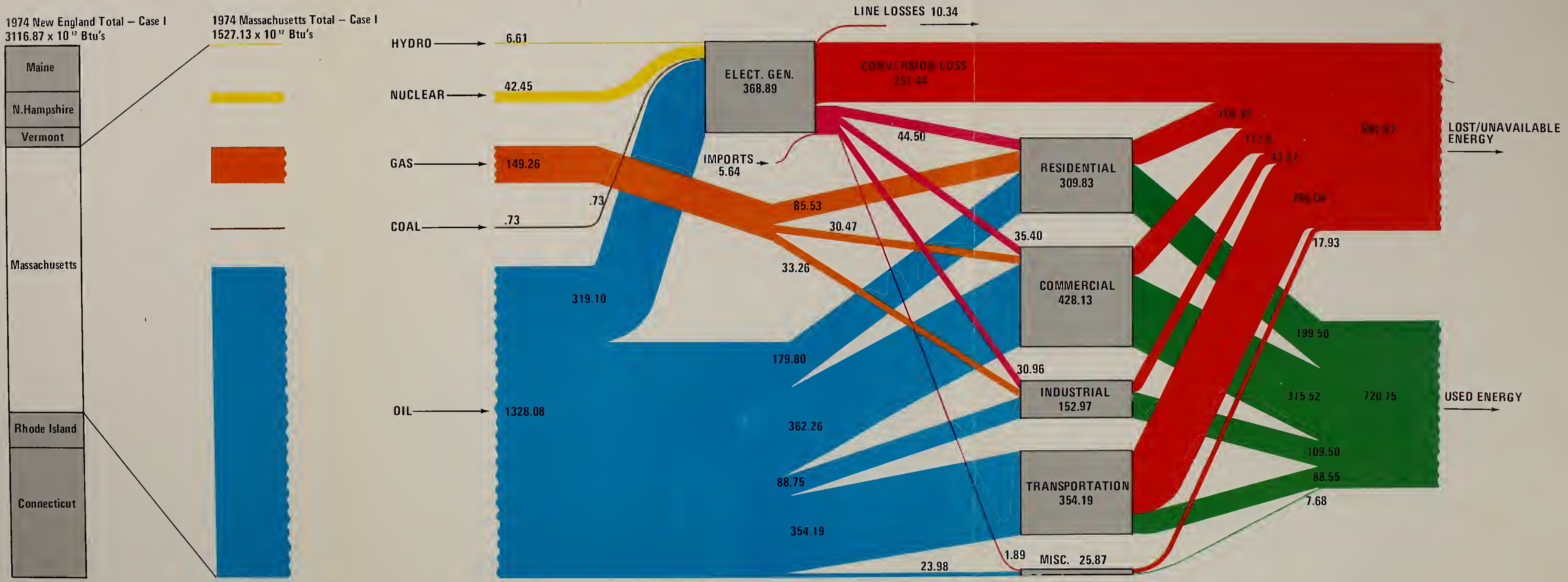


1974 MASSACHUSETTS ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
14



1980 MASSACHUSETTS ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
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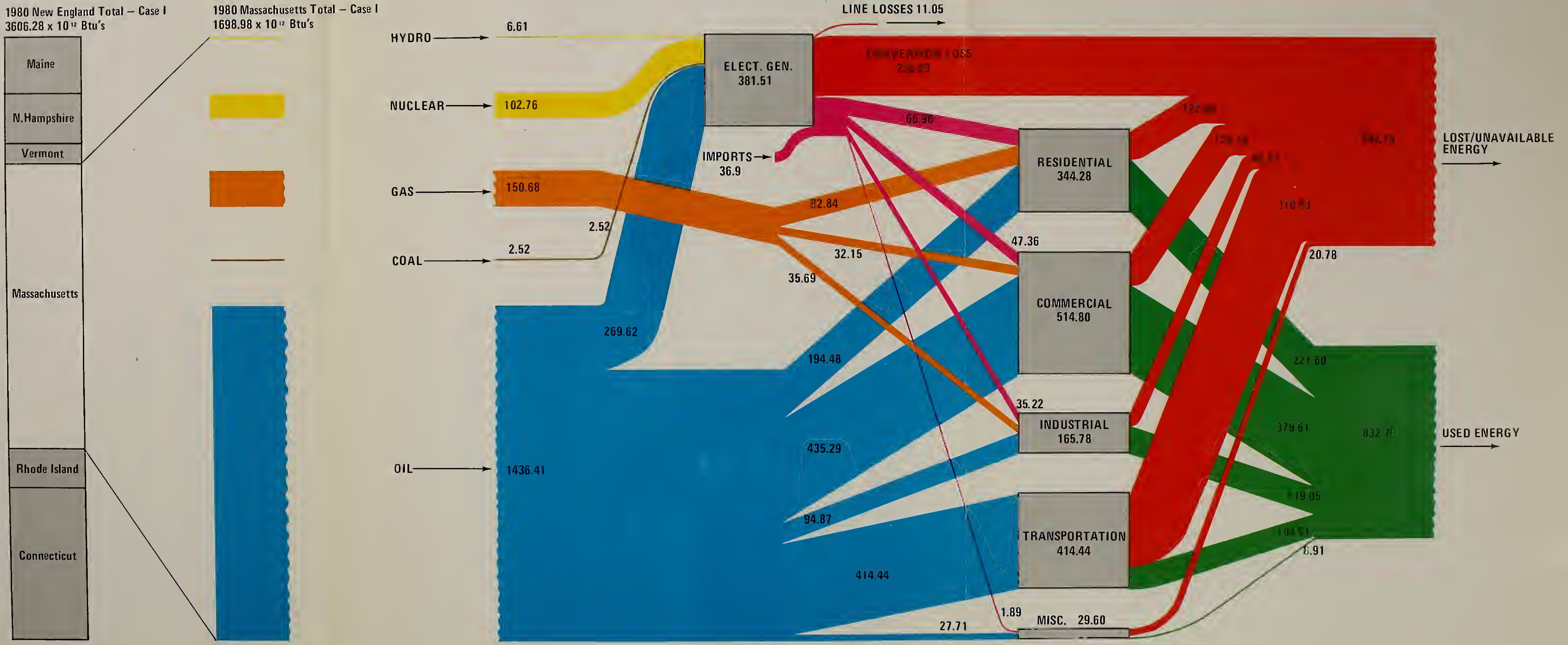


1980 MASSACHUSETTS ENERGY FLOWS — CASE II

(x 10^{12} Btu's)

EXHIBIT 16

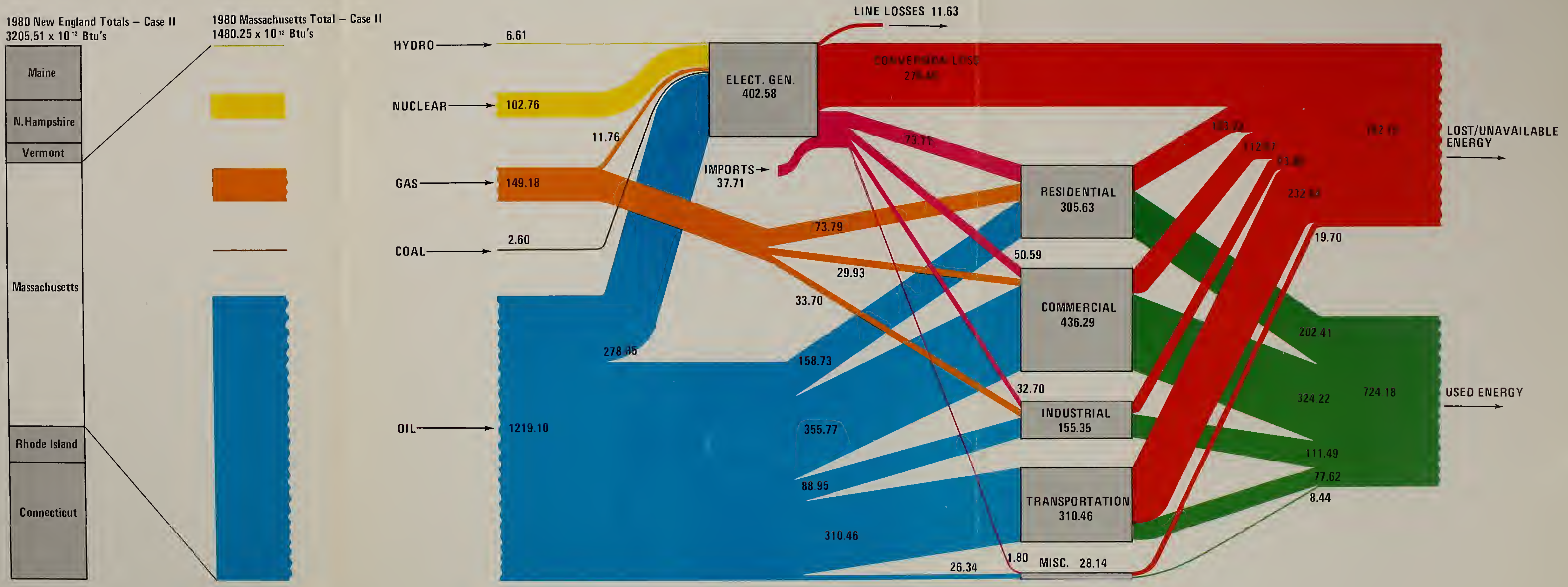
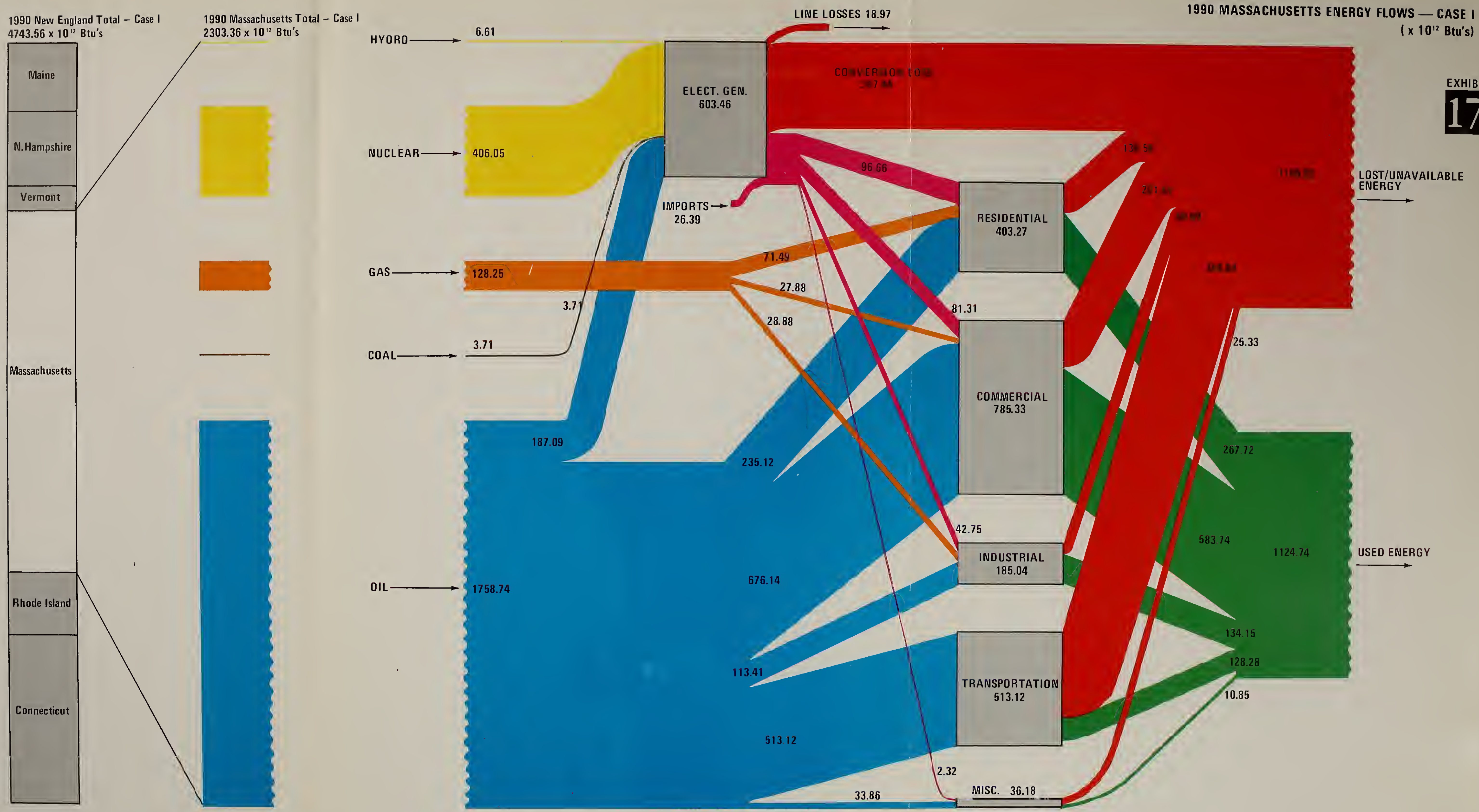


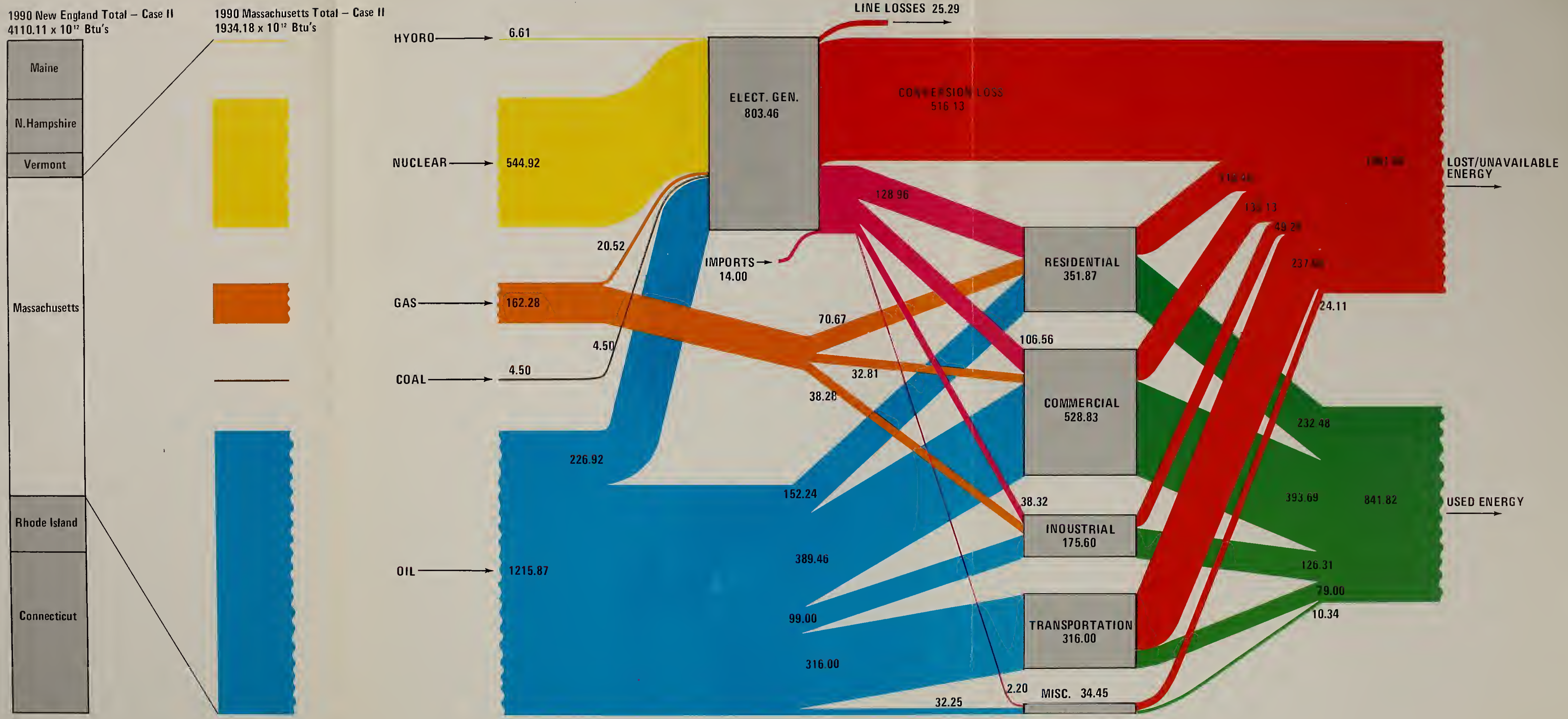
EXHIBIT 17

1990 MASSACHUSETTS ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

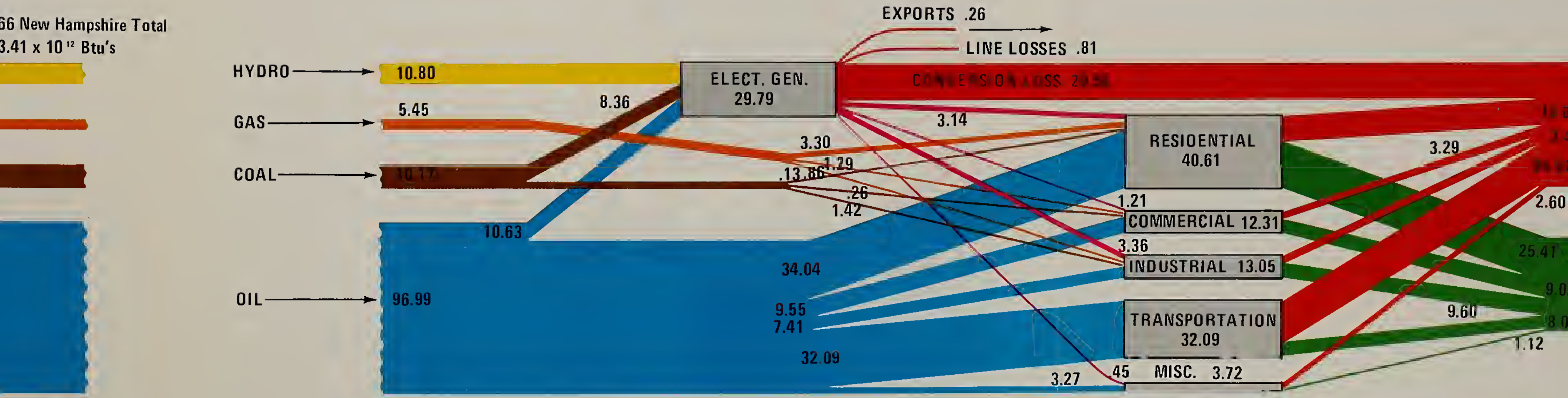


1990 MASSACHUSETTS ENERGY FLOWS — CASE II
(x 10¹² Btu's)

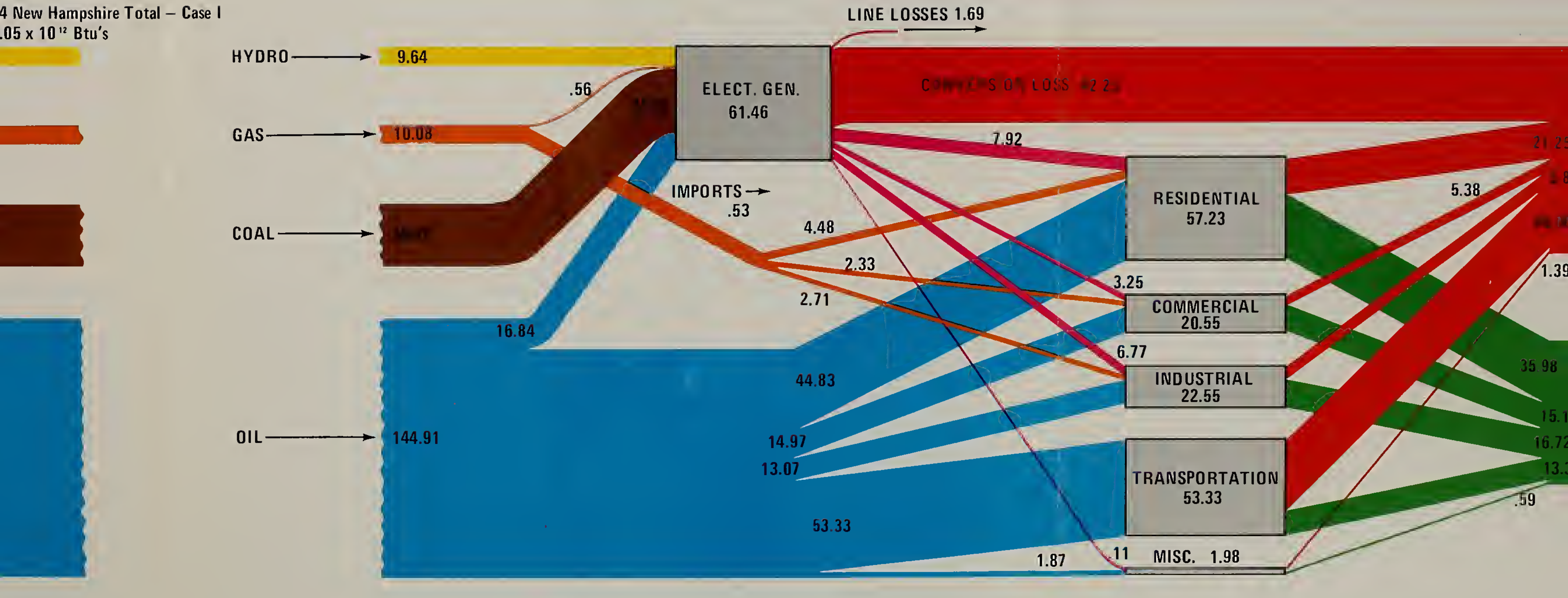
EXHIBIT 18

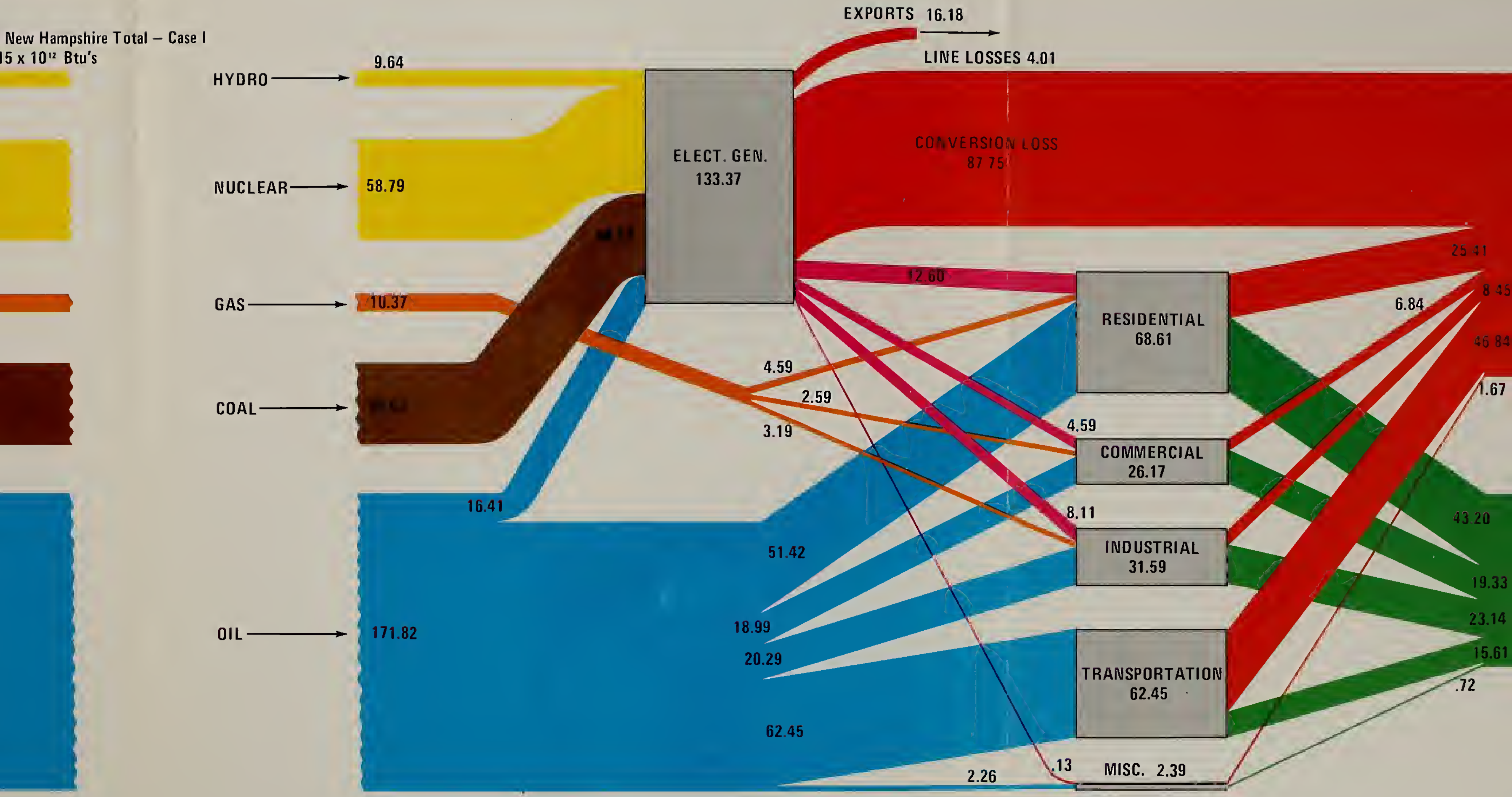


66 New Hampshire Total
3.41 x 10^{12} Btu's



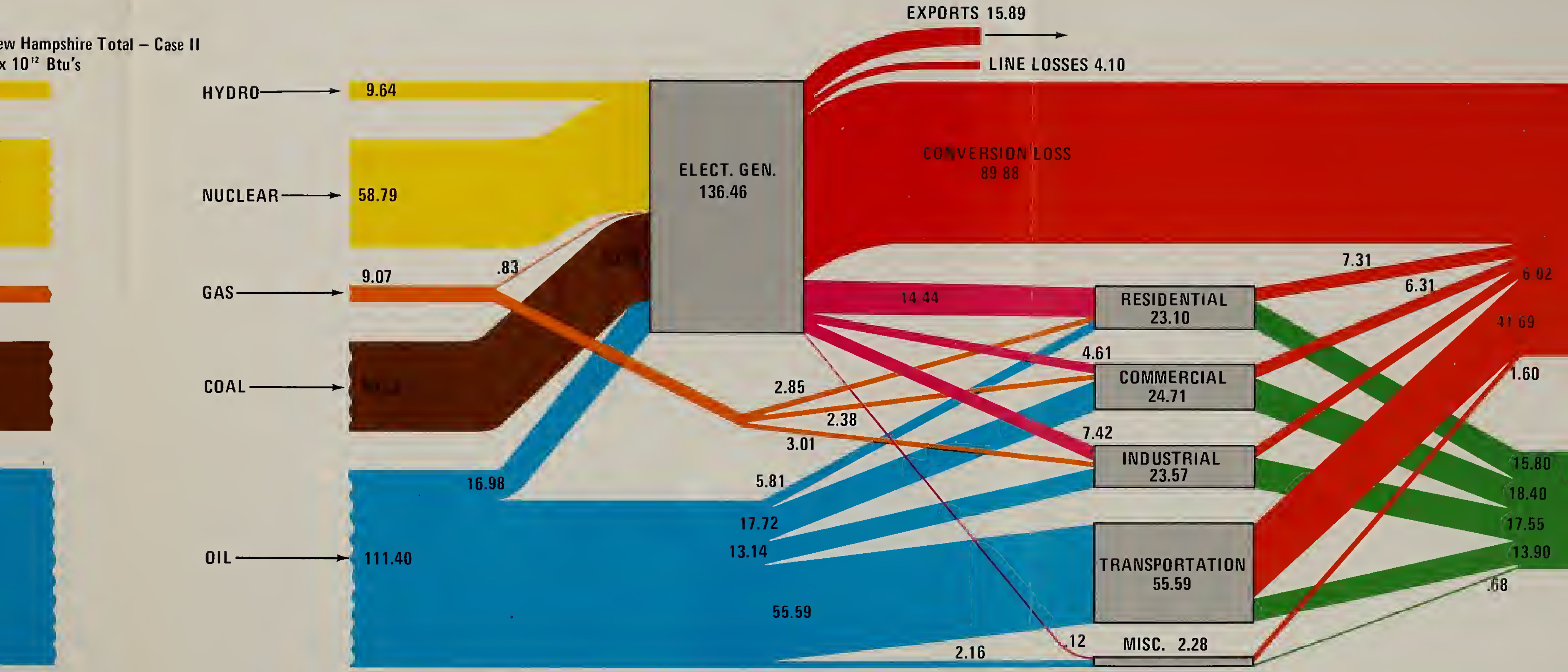
4 New Hampshire Total – Case I
.05 x 10^{12} Btu's

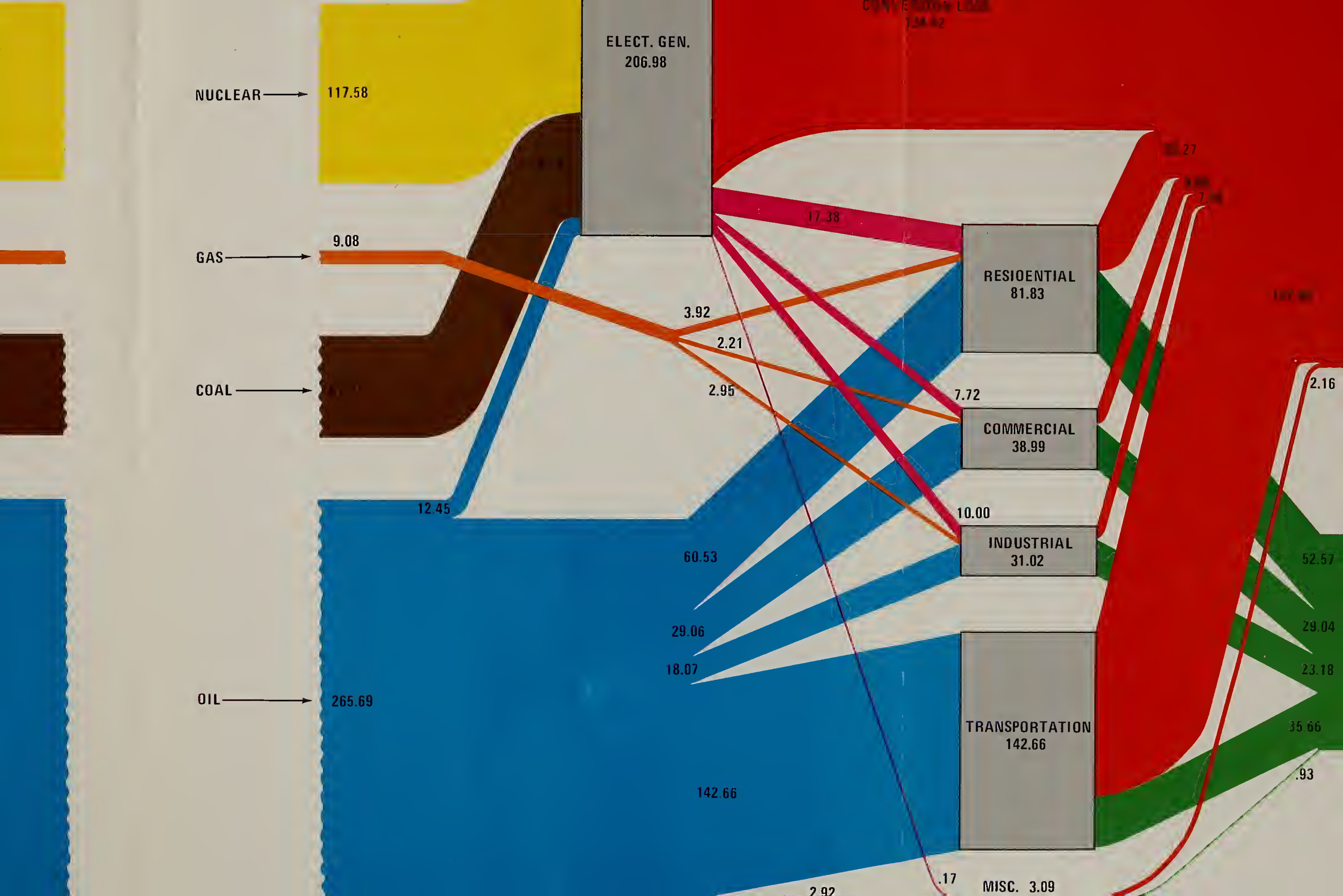




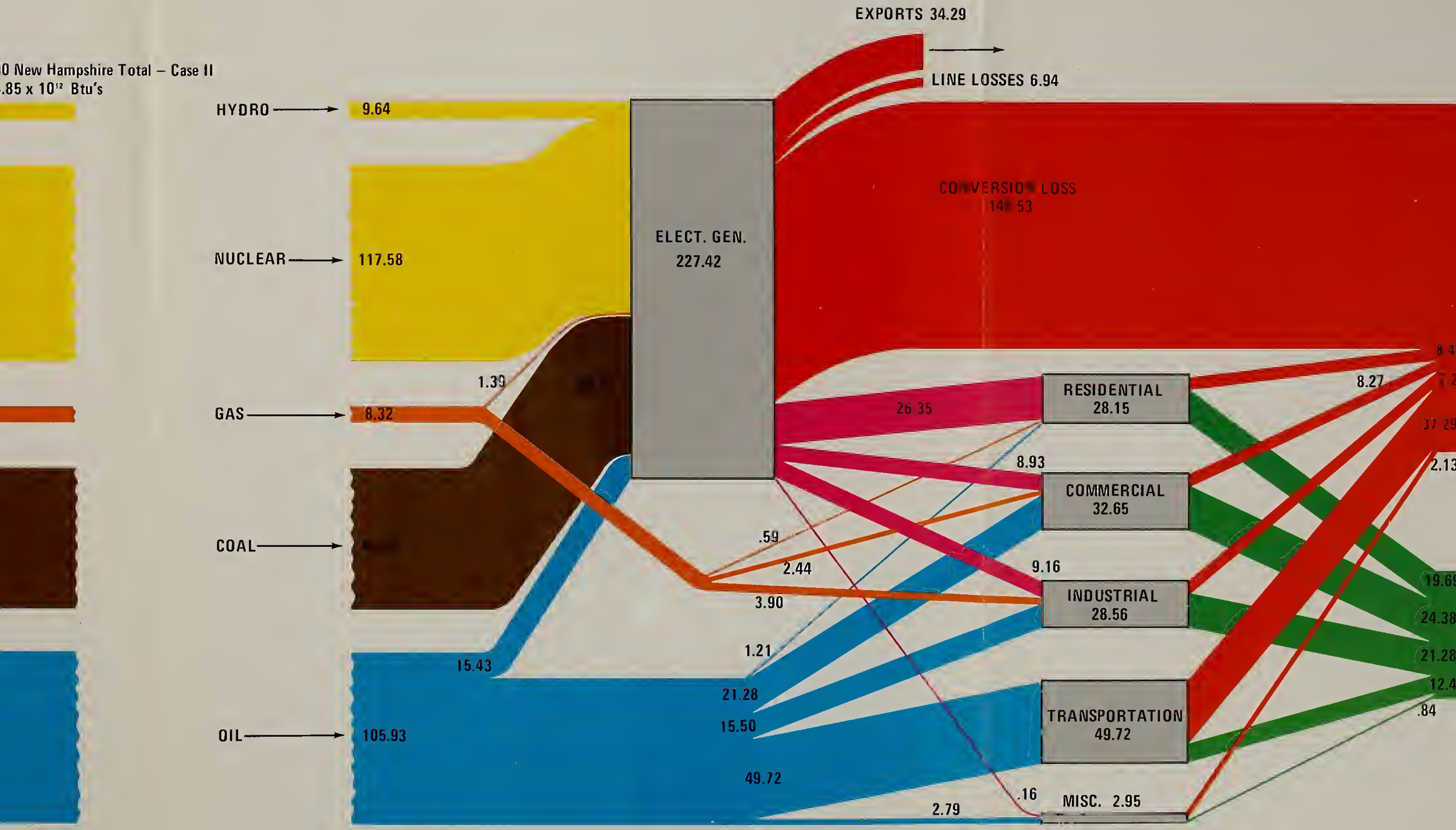
New Hampshire Total – Case I
5 x 10^{12} Btu's

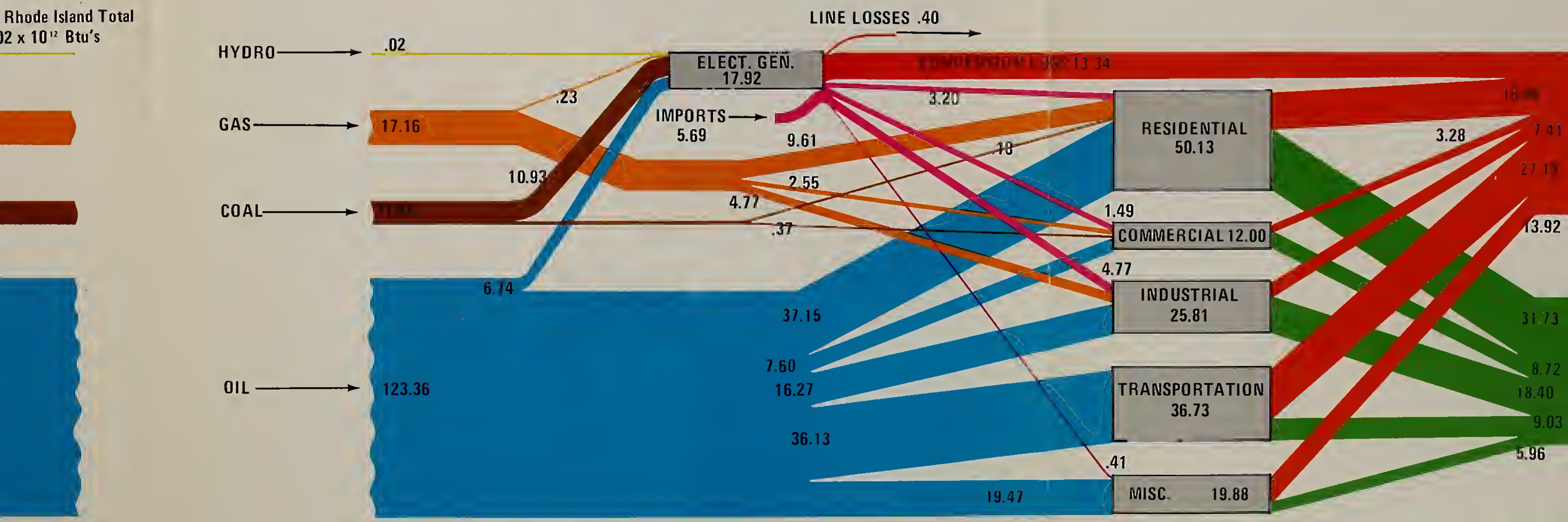
ew Hampshire Total – Case II
x 10^{12} Btu's



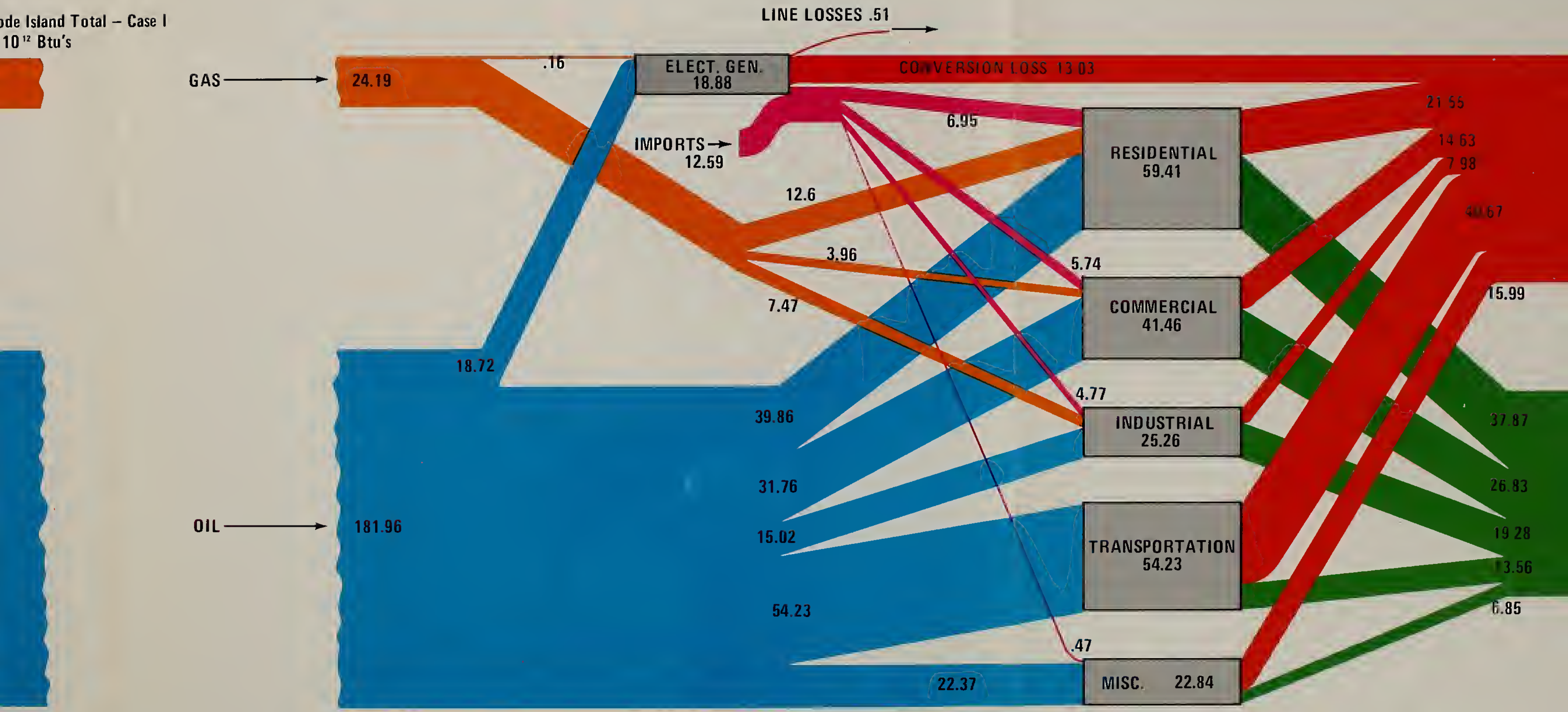

CONVERSION LOSS
134.42
ELECT. GEN.
206.98
NUCLEAR
117.58
GAS
9.08
COAL
OIL
265.69
12.45
17.38
3.92
2.21
2.95
7.72
10.00
RESIOENTIAL
81.83
COMMERCIAL
38.99
INDUSTRIAL
31.02
TRANSPORTATION
142.66
60.53
29.06
18.07
142.66
2.92
.17
MISC. 3.09
27
7.
2.16
52.57
29.04
23.18
35.66
.93

0 New Hampshire Total – Case II
.85 x 10^{12} Btu's

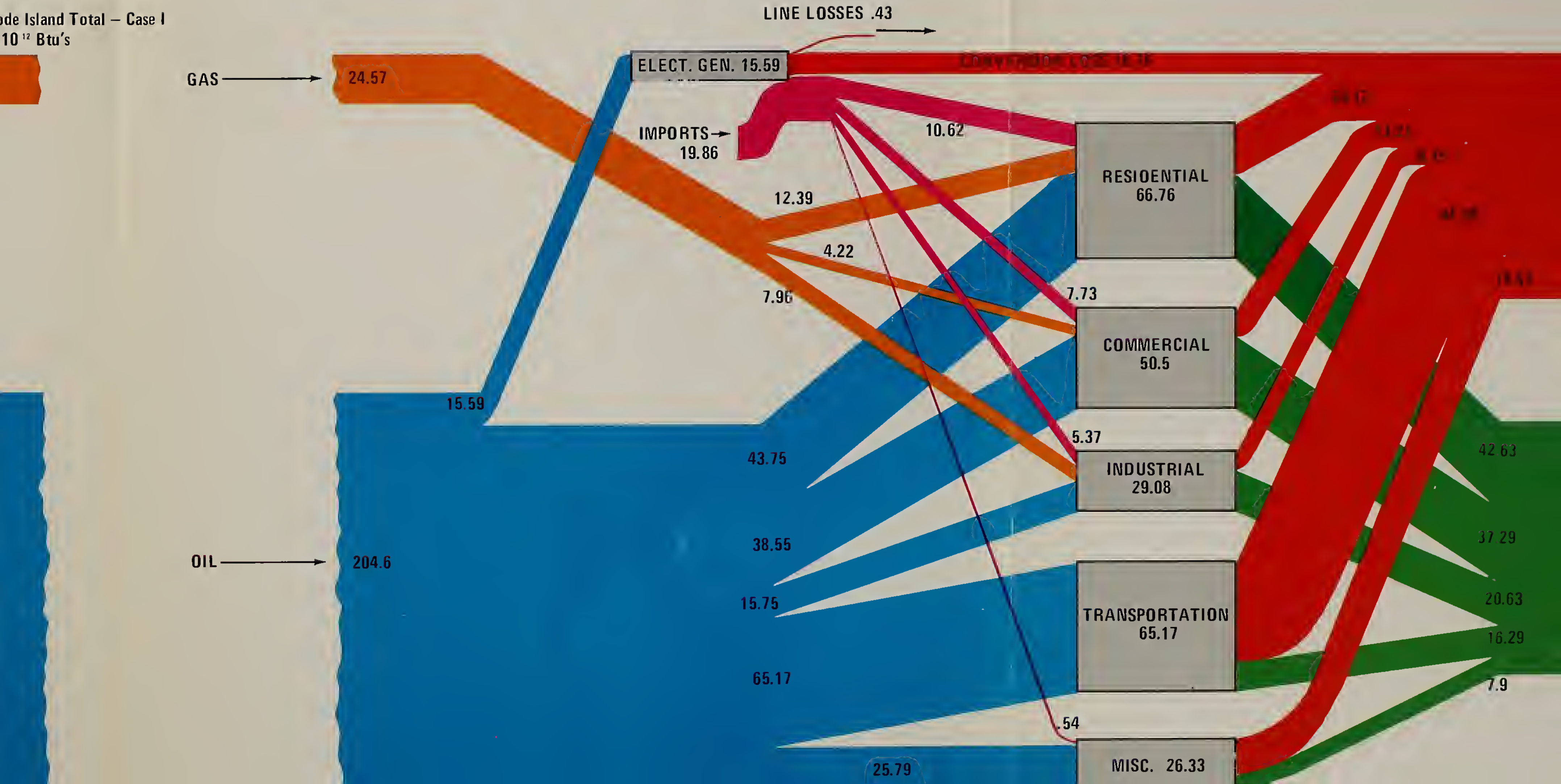



Rhode Island Total
02 x 10¹² Btu's
HYDRO
.02
GAS
17.16
COAL
OIL
123.36
.23
10.93
6.74
ELECT. GEN.
17.92
IMPORTS
5.69
LINE LOSSES .40
CONVERSION LOSS 13.34
3.20
9.61
.18
2.55
4.77
.37
37.15
7.60
16.27
36.13
19.47
.41
1.49
4.77
RESIDENTIAL
50.13
COMMERCIAL 12.00
INDUSTRIAL
25.81
TRANSPORTATION
36.73
MISC. 19.88
3.28
7.41
13.92
31.73
8.72
18.40
9.03
5.96

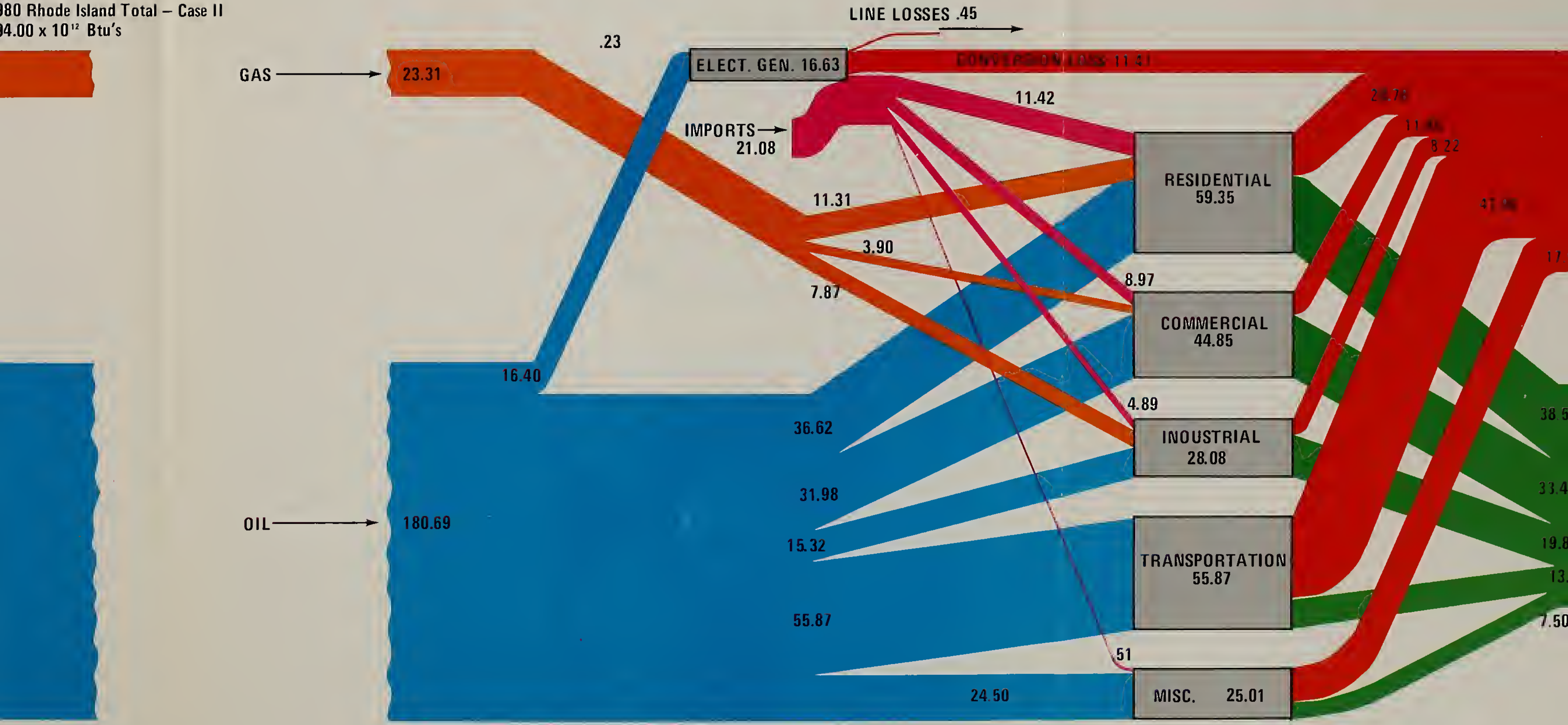
ode Island Total – Case I
10^{12} Btu's

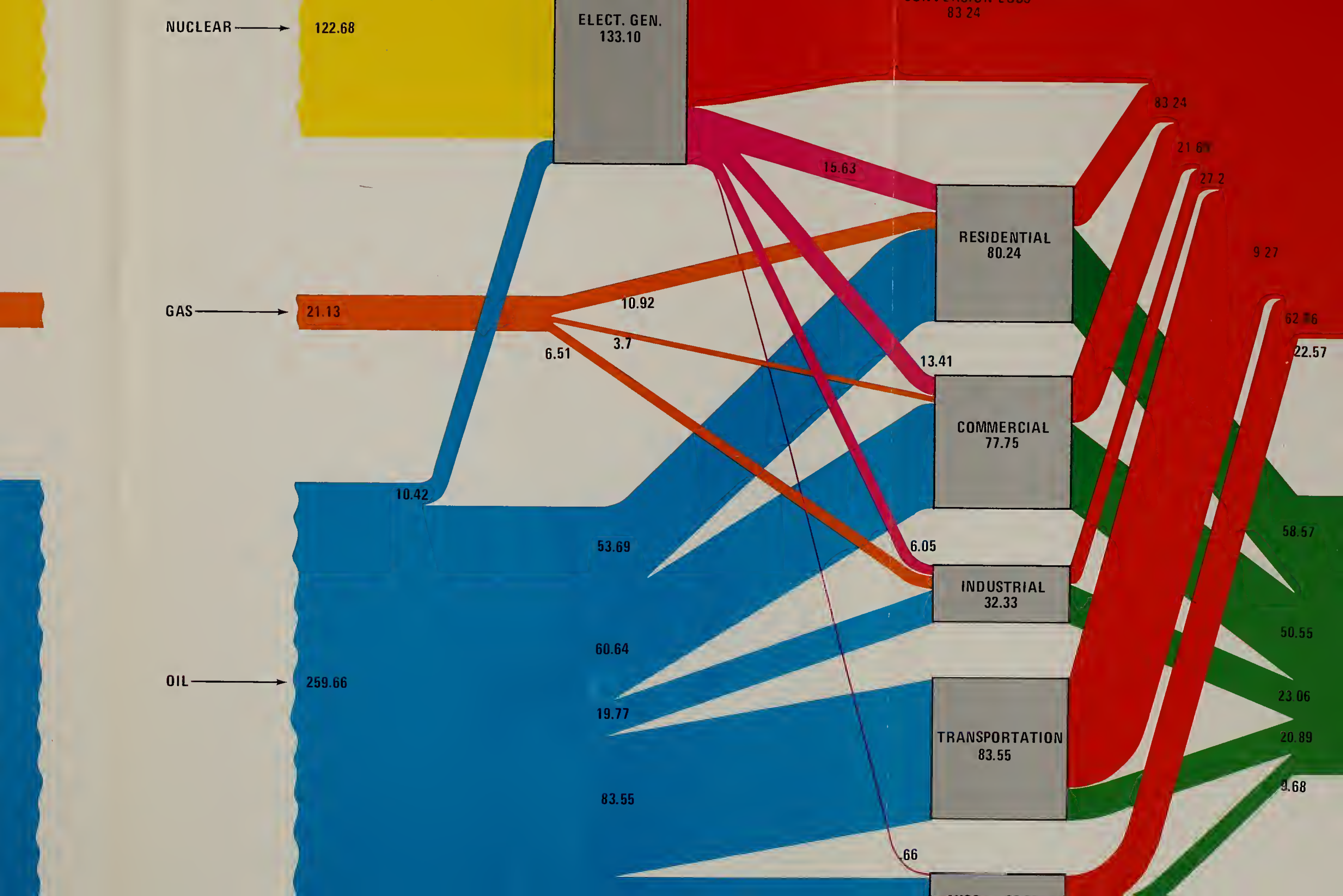


ode Island Total – Case I
10^{12} Btu's



980 Rhode Island Total – Case II
04.00 x 10^{12} Btu's




NUCLEAR
122.68
ELECT. GEN.
133.10
83 24
83 24
21 6
27 2
15.63
RESIDENTIAL
80.24
9 27
GAS
21.13
10.92
3.7
6.51
13.41
62 6
22.57
COMMERCIAL
77.75
10.42
53.69
58.57
6.05
INDUSTRIAL
32.33
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OIL
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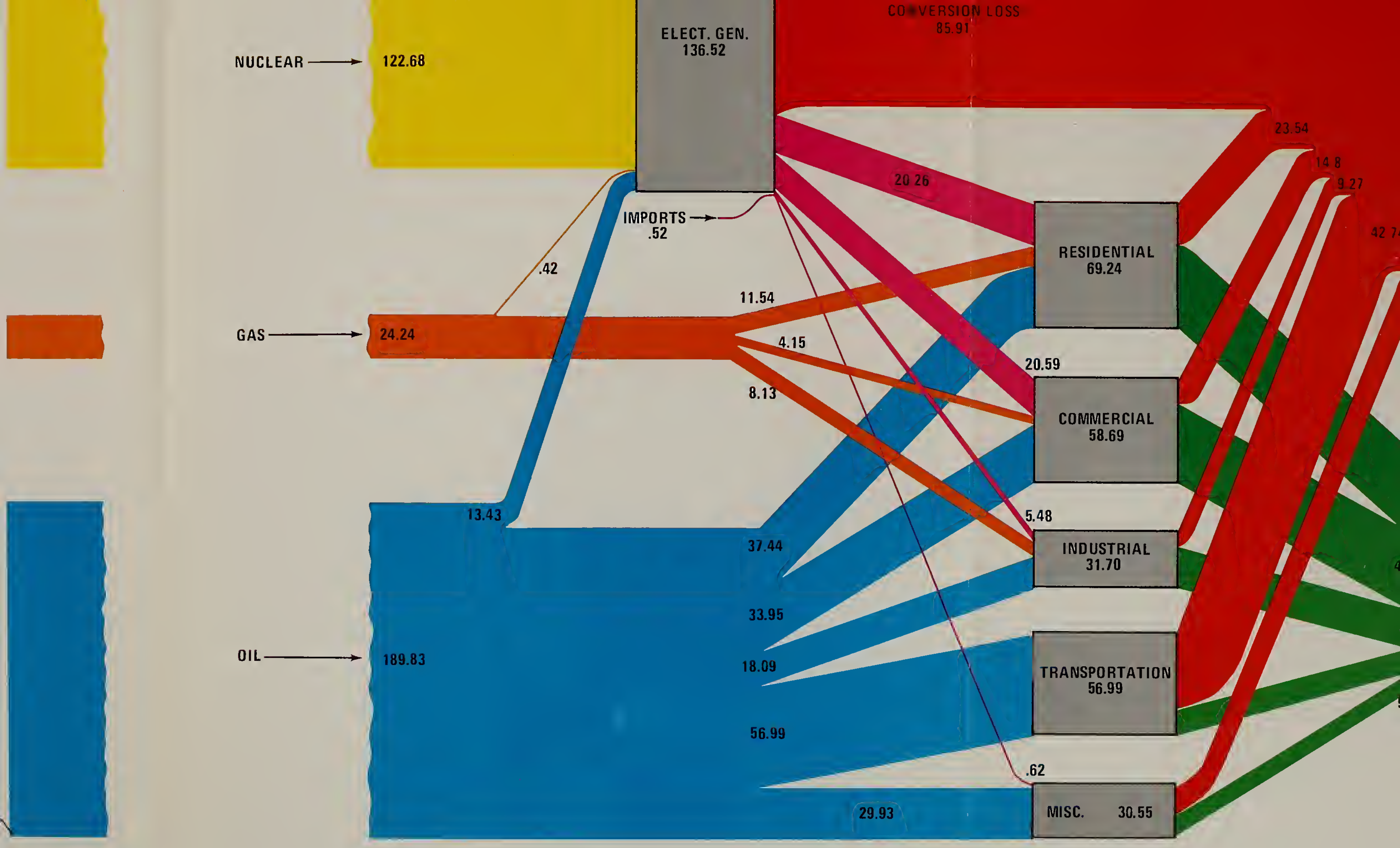
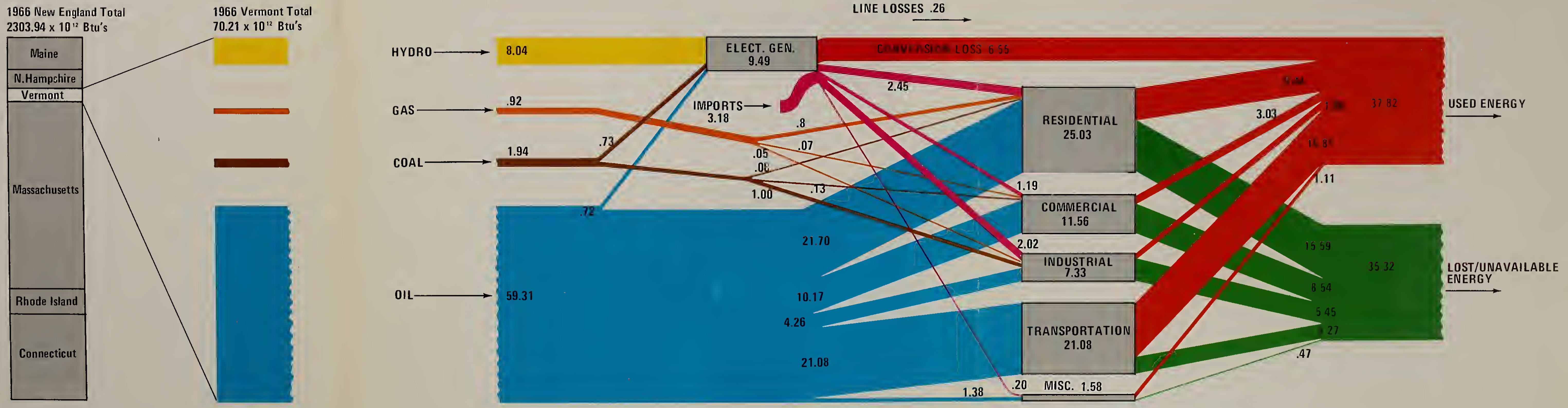
TRANSPORTATION
83.55
20.89
83.55
9.68
.66


CONVERSION LOSS
85.91
ELECT. GEN.
136.52
NUCLEAR
122.68
IMPORTS
.52
.42
GAS
24.24
11.54
4.15
8.13
20 26
23.54
14 8
9 27
42 7
RESIDENTIAL
69.24
20.59
COMMERCIAL
58.69
5.48
INDUSTRIAL
31.70
TRANSPORTATION
56.99
.62
MISC.
30.55
OIL
189.83
13.43
37.44
33.95
18.09
56.99
29.93

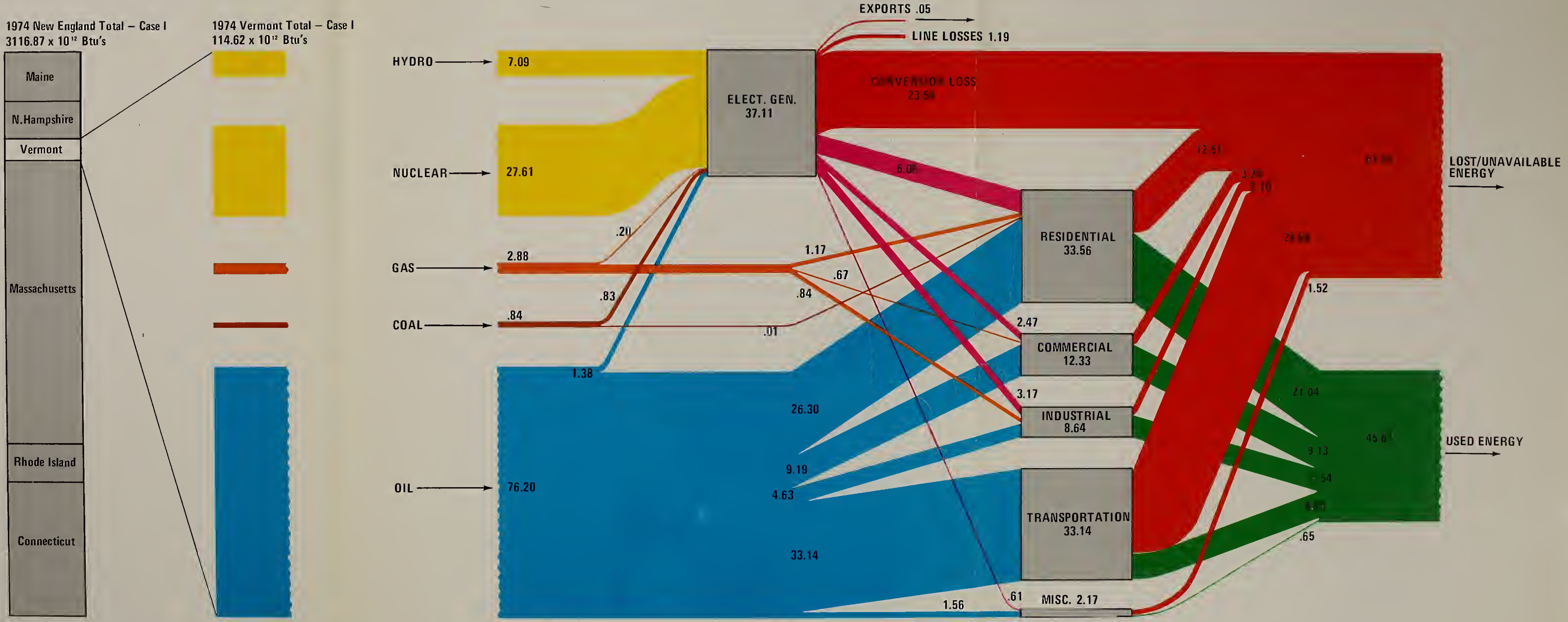
1966 VERMONT ENERGY FLOWS
(x 10^{12} Btu's)

EXHIBIT
31



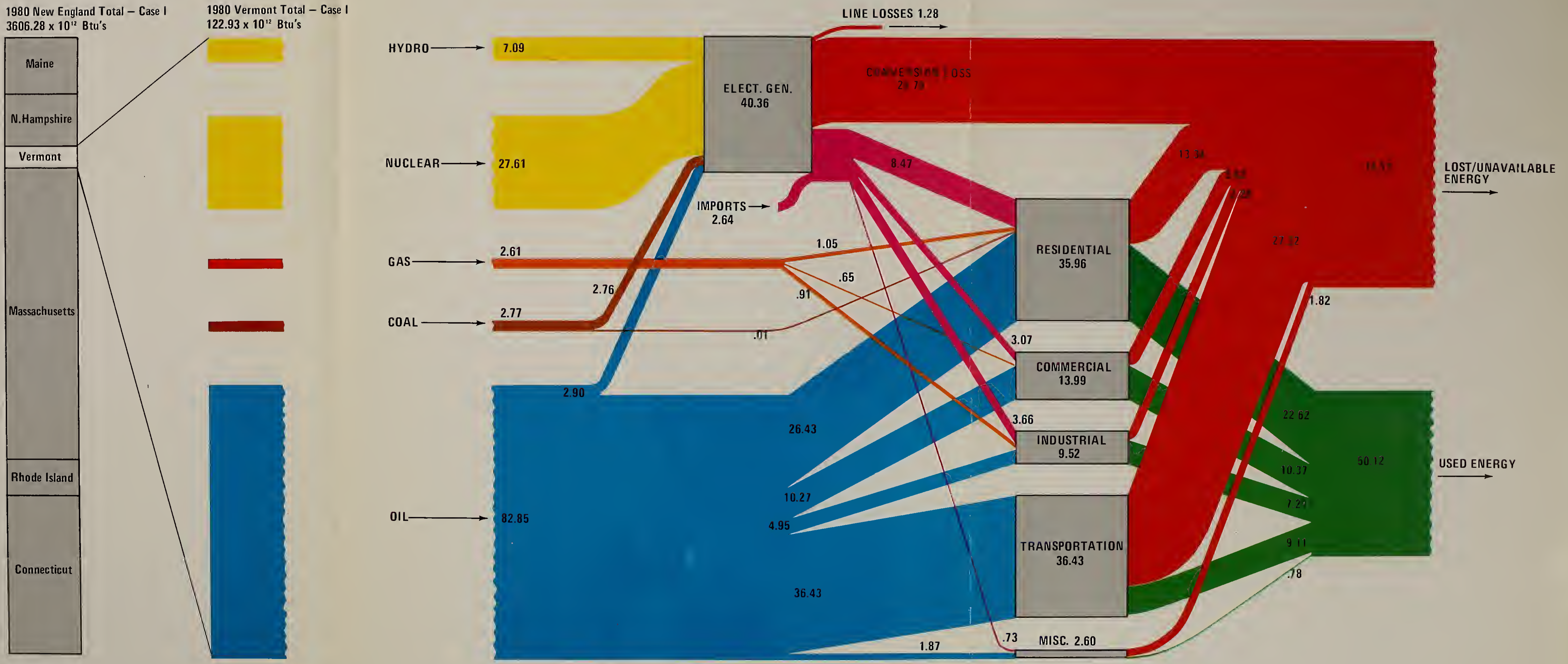
1974 VERMONT ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
32



1980 VERMONT ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT 33



1980 VERMONT ENERGY FLOWS — CASE II
(x 10^{12} Btu's)

EXHIBIT
34

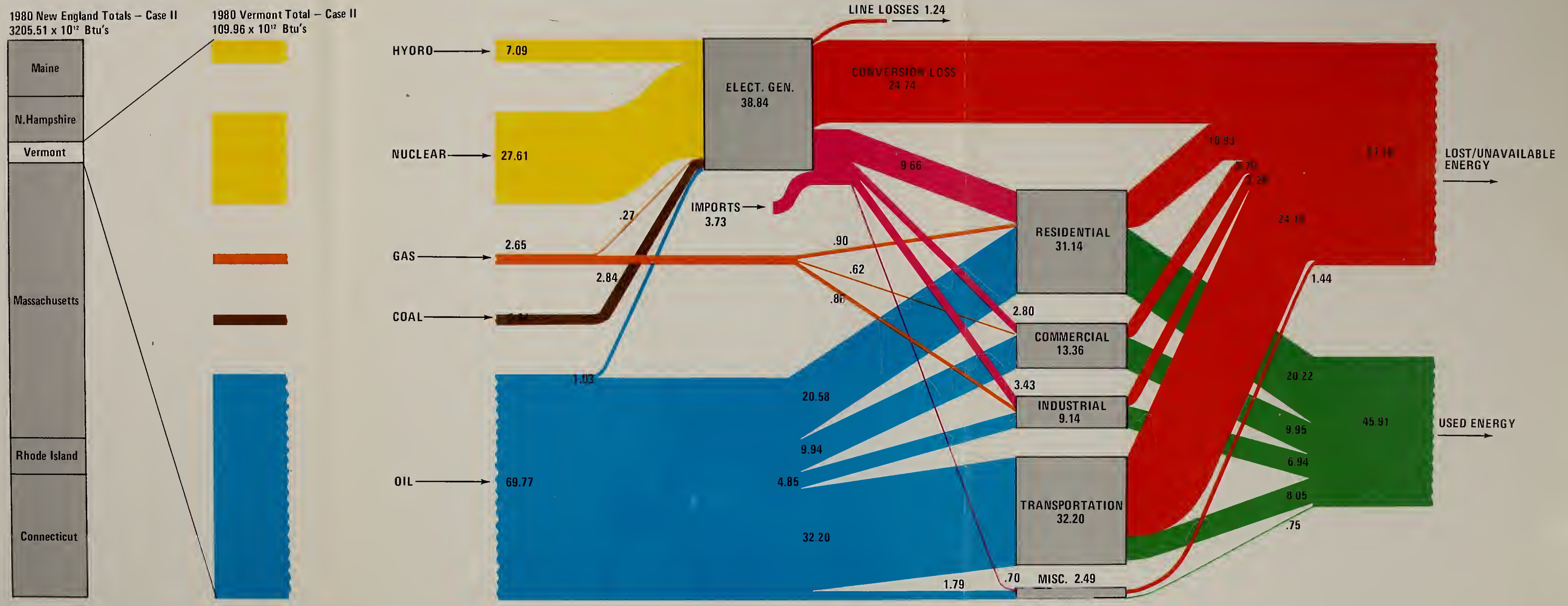
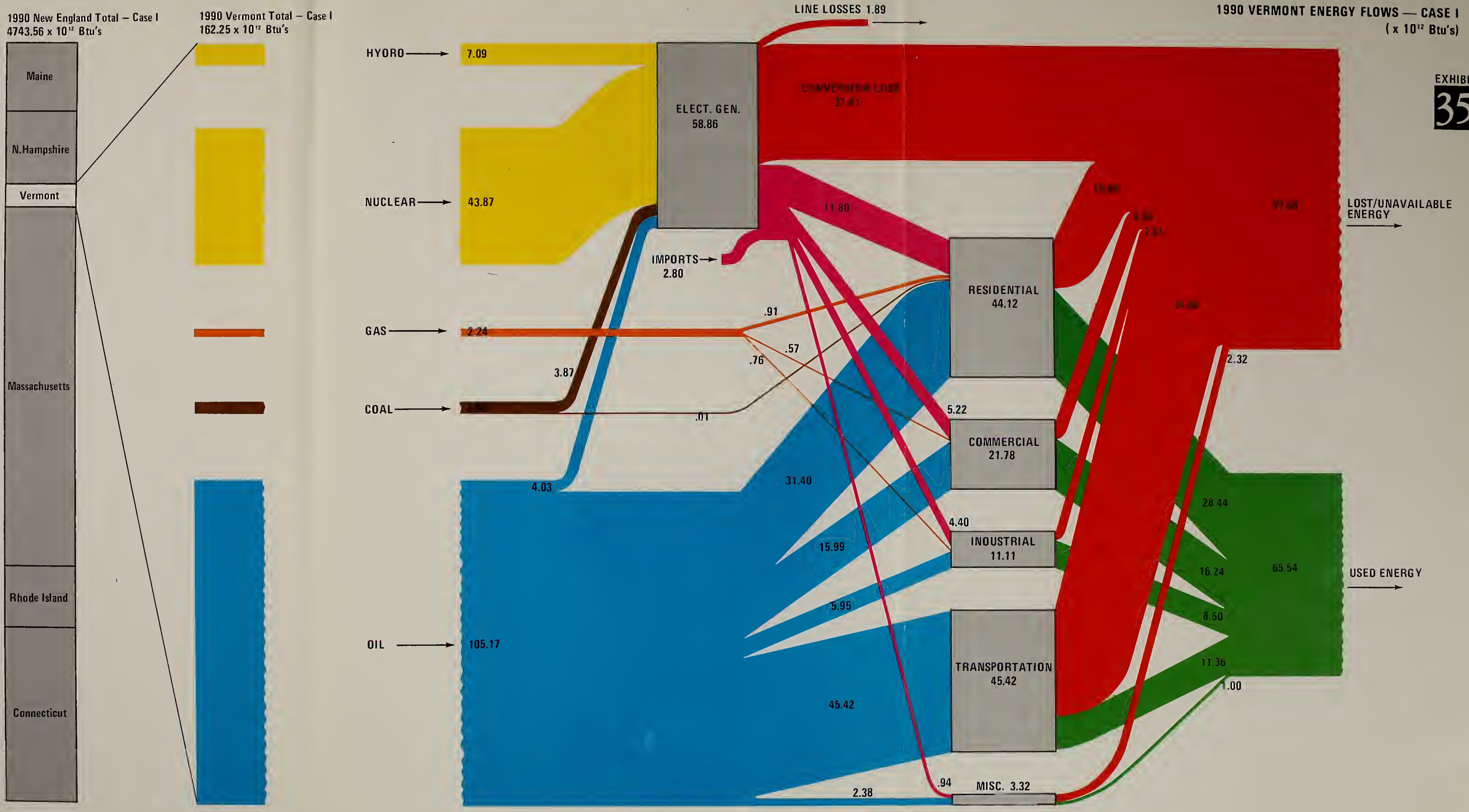


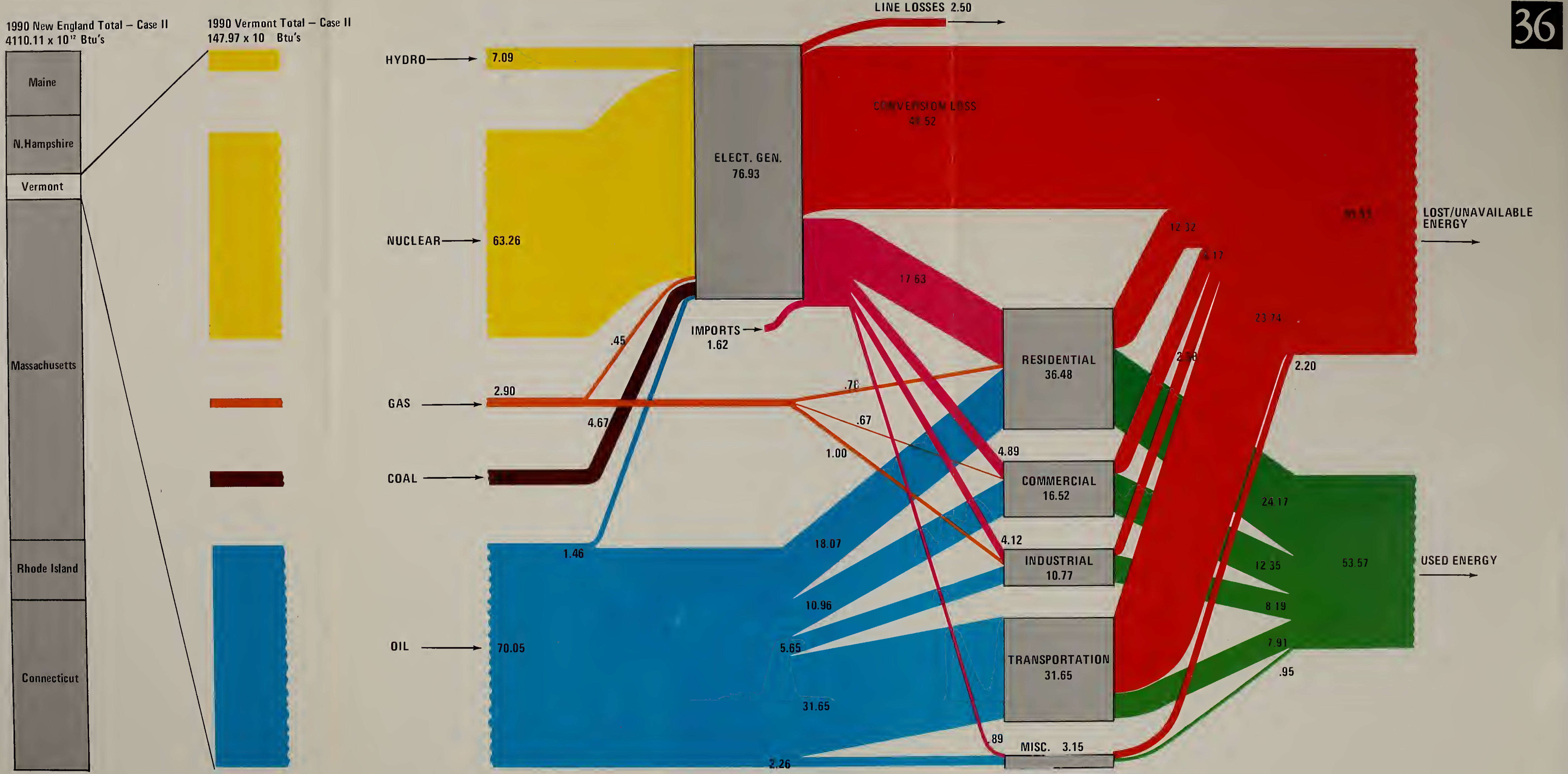
EXHIBIT 35

1990 VERMONT ENERGY FLOWS — CASE I
(x 10¹² Btu's)



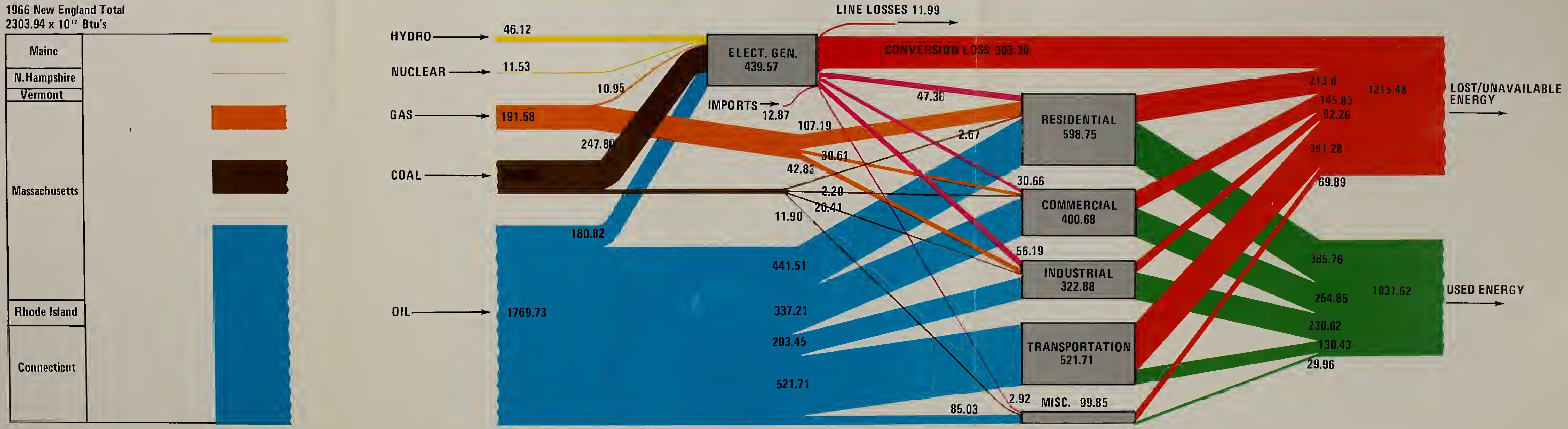
1990 VERMONT ENERGY FLOWS — CASE II
(x 10^{12} Btu's)

EXHIBIT 36



1966 NEW ENGLAND ENERGY FLOWS
(x 10^{12} Btu's)

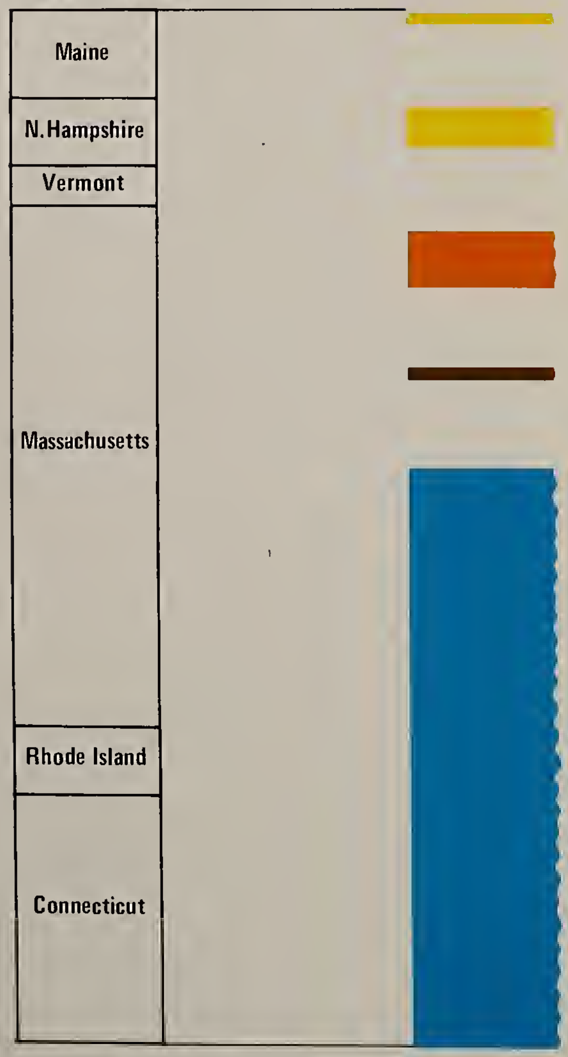
EXHIBIT 37

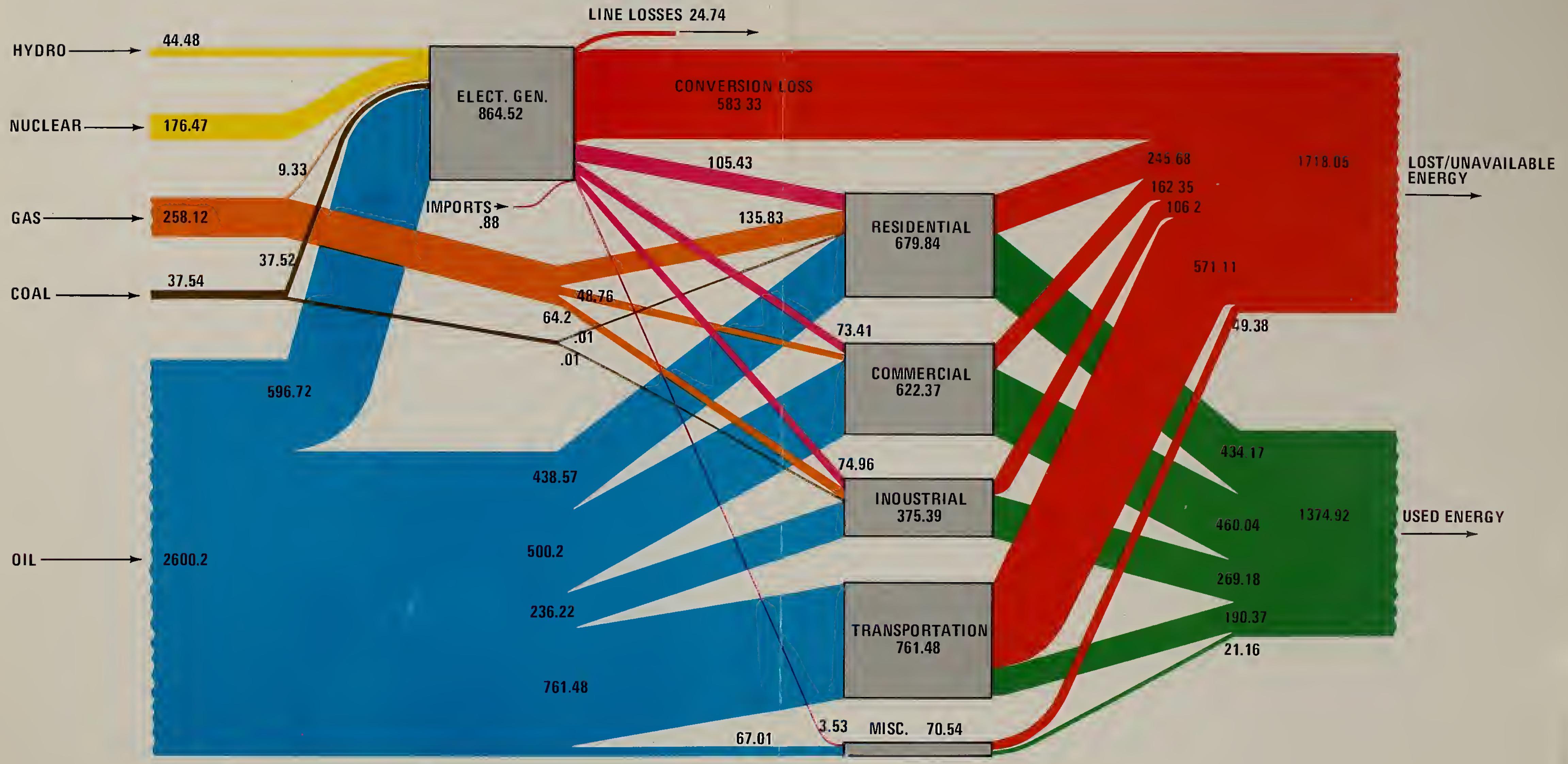


1974 NEW ENGLAND ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
38

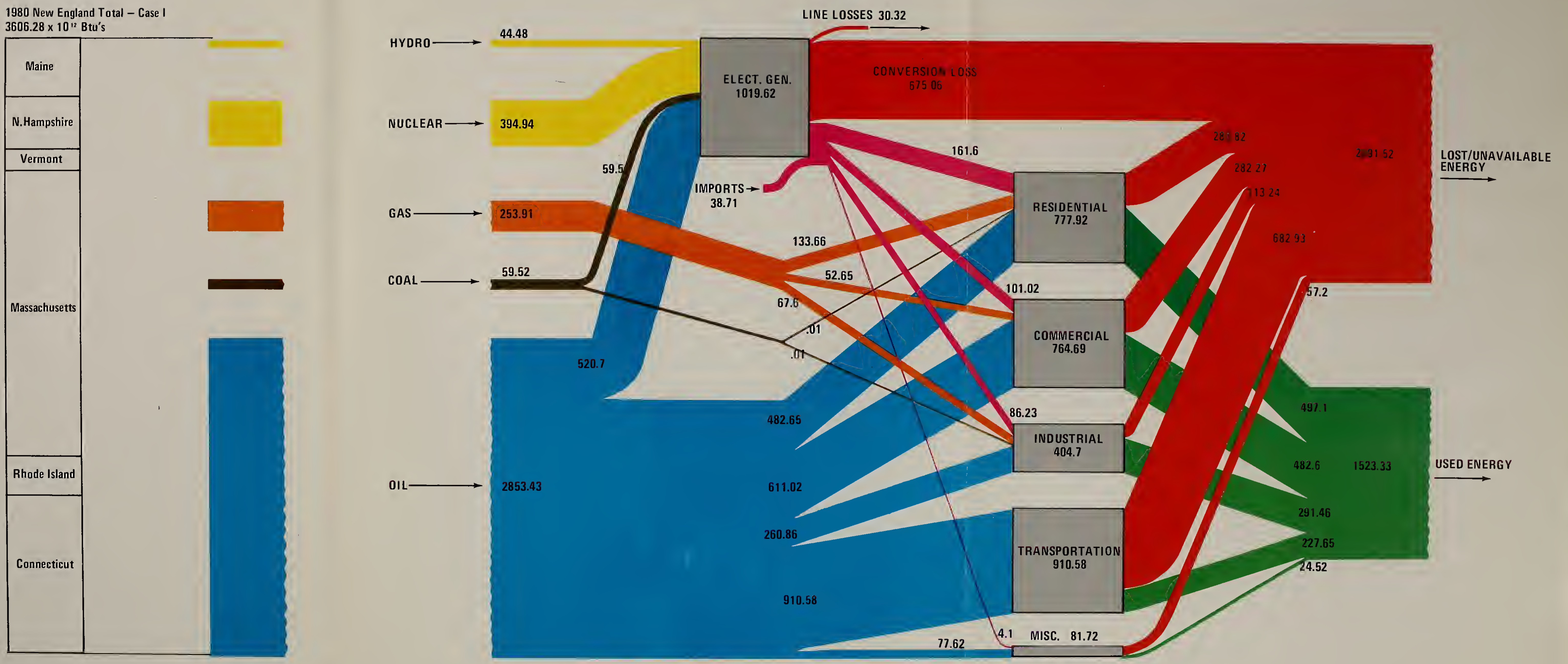
1974 New England Total – Case I
3116.87 x 10^{12} Btu's





1980 NEW ENGLAND ENERGY FLOWS — CASE I
(x 10^{12} Btu's)

EXHIBIT
39



1980 NEW ENGLAND ENERGY FLOWS — CASE II
(x 10^{12} Btu's)

EXHIBIT
40

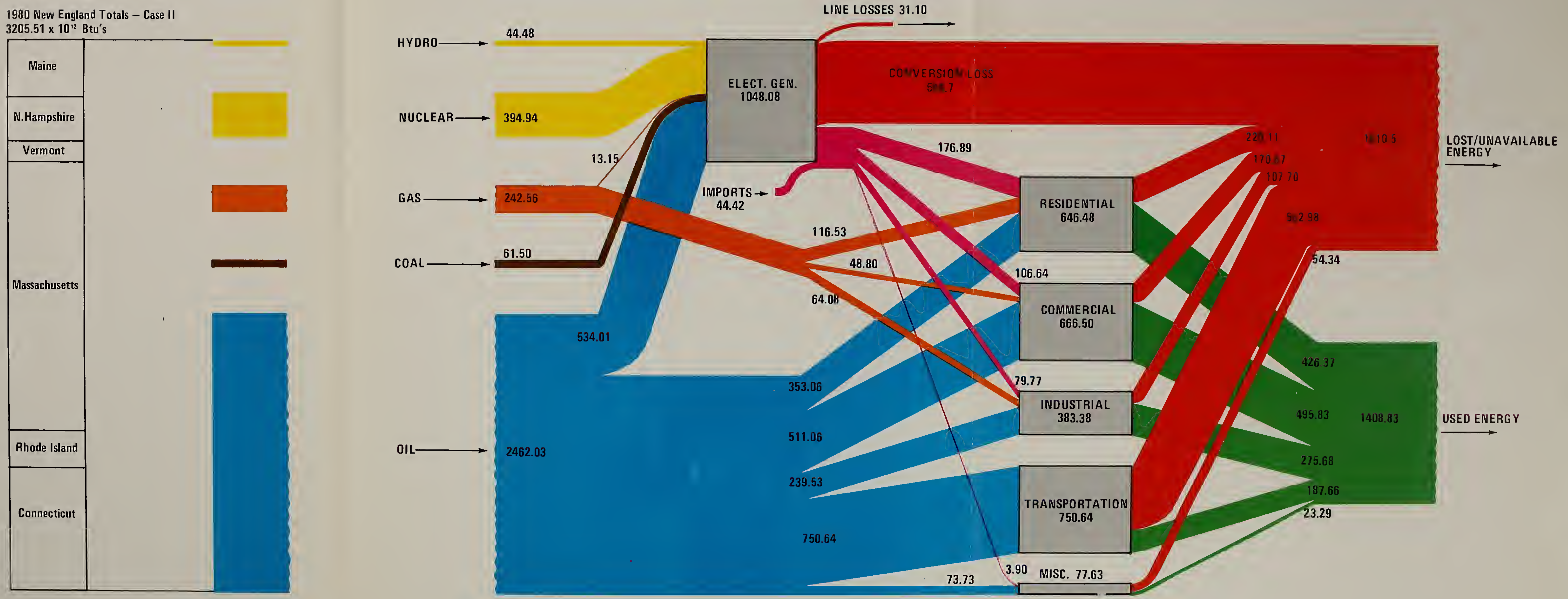
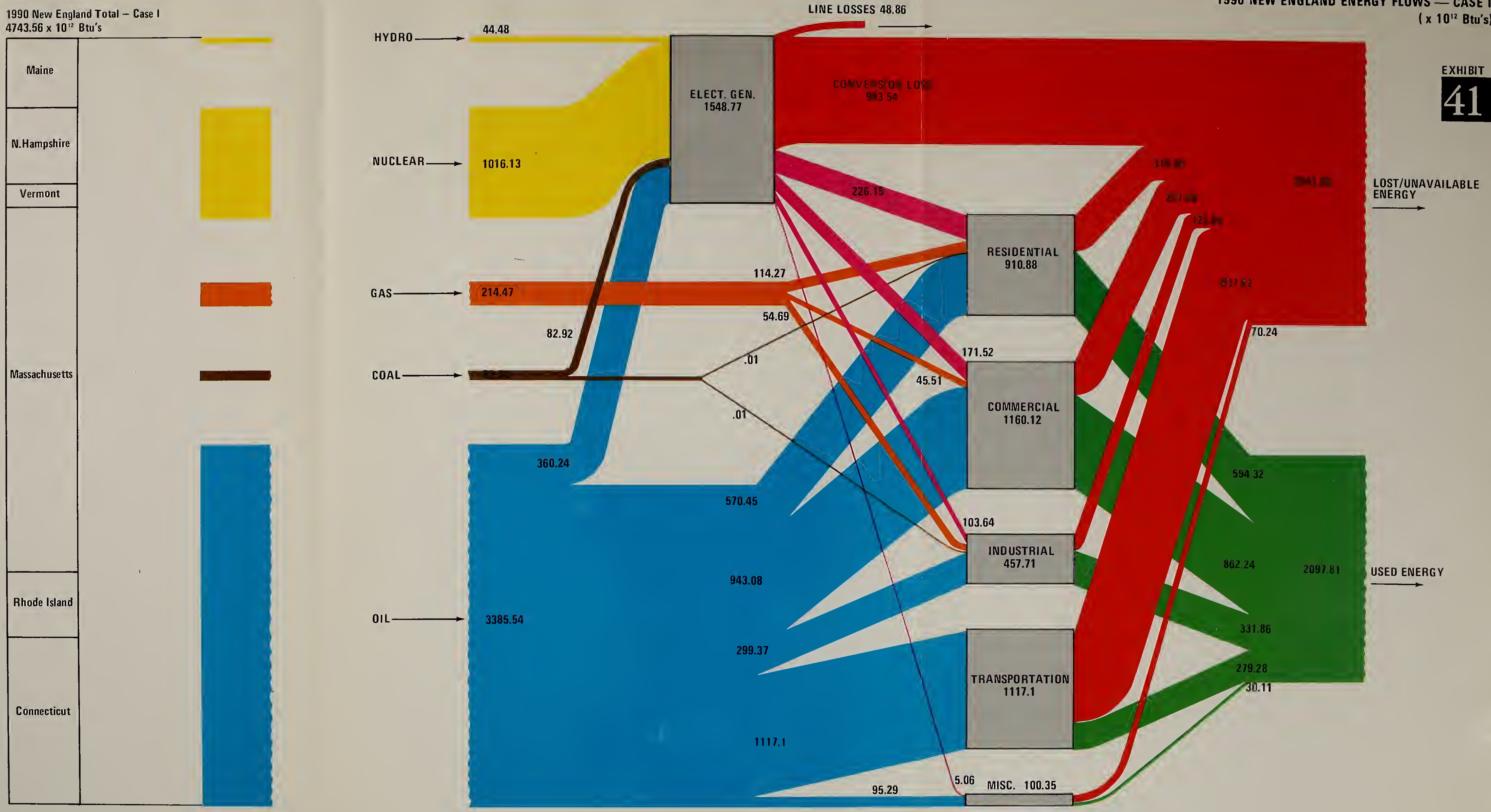


EXHIBIT 41

1990 NEW ENGLAND ENERGY FLOWS — CASE I
(x 10^{12} Btu's)



1990 NEW ENGLAND ENERGY FLOWS — CASE II
(x 10^{12} Btu's)

EXHIBIT
42